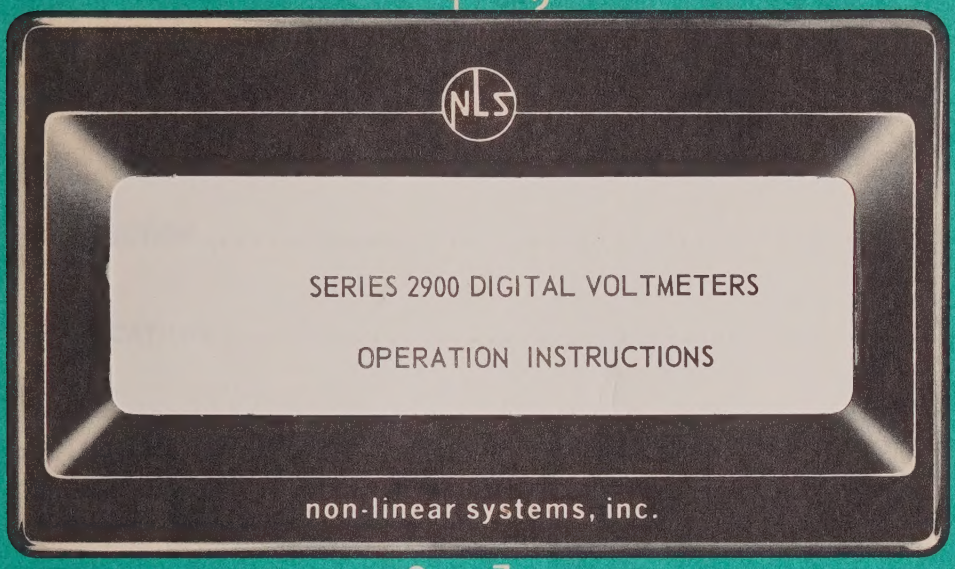

SERIES 2900 DIGITAL VOLTMETERS

OPERATION INSTRUCTIONS

M13767X
Electronic Services Los Angele

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Instrumentation & Control
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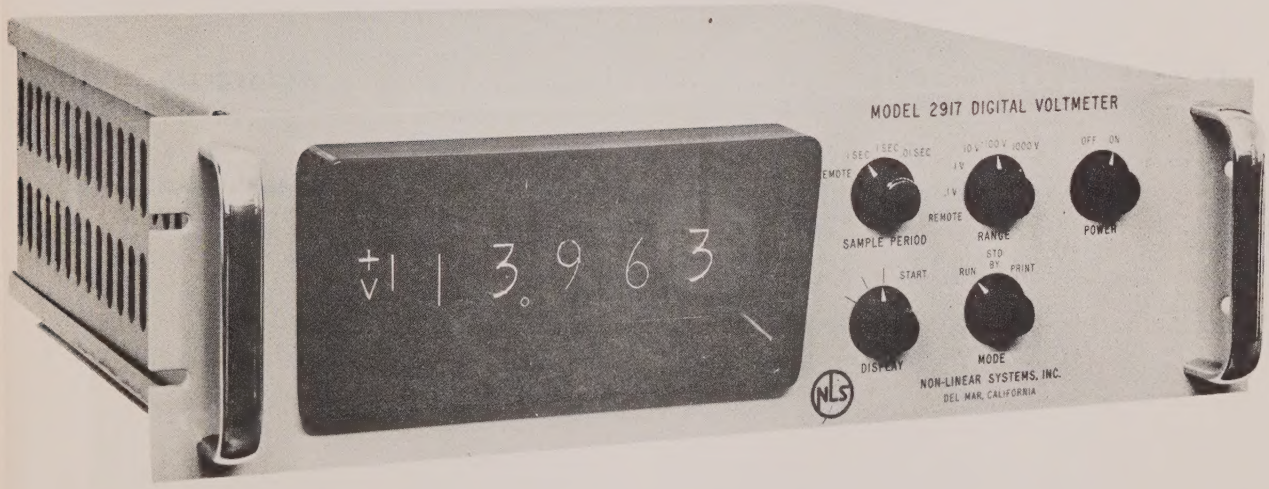
non linear systems, inc.

DEL MAR, CALIFORNIA

This manual is for instrument Serial No._____

SERIES 2900 DIGITAL VOLTMETERS

OPERATION INSTRUMENTS



Originator of the Digital Voltmeter

non-linear systems, inc.

DEL MAR , CALIFORNIA

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1

INTRODUCTION

The NLS 2900 Series Digital Voltmeters are solid-state integrating instruments which measure the absolute value of DC voltages or the true integral of varying voltages. In these instruments the unknown input voltage is converted to a pulse train whose repetition rate is directly proportional to the input voltage magnitude. The total number of pulses generated over an accurately clocked one-second interval is counted electronically and displayed as the voltage value.

OPERATING PRINCIPLE

In a typical instrument, an input of 100 millivolts creates 100,000 pulses in one second; this is displayed as 100.000 MV. If the input voltages change during the measuring interval, the pulse repetition rate changes proportionately, and the total number of pulses that occurs during the one-second sample period is a measure of the number of volt-seconds at the input. Since these instruments mathematically integrate the input voltage, they are useful for obtaining the velocity from a voltage which is proportional to acceleration. In addition, these instruments are inherently able to reject sinusoidal ripple because the integrated value of an integral number of sine waves is zero. Therefore if an integral number of cycles of sine-wave noise occurs during the one-second sampling interval, its contribution to the over-all reading is "integrated out". It should be noted that with a .01 second sampling rate there is not time for an entire 60-cycle sine wave and some measurement inaccuracy would occur; however at the instrument's slower sampling rates, the error is reduced to negligible value. With sine-wave noise of 400 cycles, high reading accuracy can be maintained even with a .01 second sampling rate.

THE REVERSIBLE COUNTER

The NLS 2900 Series instruments are uniquely able to provide a higher order of accuracy than that available with other integrating-type digital voltmeters because the NLS instruments have a reversible counter. It is only with this type of circuit that an integrating instrument can render a true average reading, for without a reversible counter, any AC component imposed upon the DC input will cause a zero-crossing error which accumulates each time the AC component causes the amplifier output to cross the zero level. More detailed information about this characteristic is contained in the Appendix.

COMMON-MODE REJECTION

As shown in the Specifications, Section 2, the common-mode rejection capability of a 2900 Series instrument is extremely high. For the most part, this is due to the use of photo-electric coupling devices which avoid the need for electrical connection at the converter output and at the range command signal connection to the converter.

STABILITY

Long-term stability and reliability are assured in part because no vacuum tubes are used in this instrument. Therefore the problems associated with changing emission levels and with heating are eliminated. The whole instrument dissipates only about 25 watts and no blower is required. In fact, the problem of heat is so minimal that only a few heat sinks are used. Because of this cool operation, the instrument is not likely to require frequent recalibration.

SCOPE OF MANUAL

This manual is intended to cover all models in the 2900 Series. The functions and measuring capabilities of each model are listed in the Table of Models which follows. For purposes of discussion, the content of this manual is focussed upon one particular instrument, the Model 2917, which is fairly representative of the Series. Users should experience no difficulty in applying this manual to other instruments in the Series if the Table of Models is consulted to determine which measuring capabilities and functions are different, since all models rely upon the same general circuits and component array. If necessary, additional schematic drawings are supplied to accommodate special needs. If problems are encountered with the instrument, the user is asked to contact the nearest NLS Service/Engineering Office.

MODELS IN THE 2900 SERIES

MEASURES			NUMBER OF		FUNCTION CONTROLS			
MODEL	VOLTS	RATIO	DIGITS	RANGES	POLAR	RANGE	PRINT	REMOTE
2901	V	–	4	1	A	F	–	–
2902	V	–	4	2	A	M	–	–
2903	V	–	4	3	A	M	–	–
2904	V	–	4	4	A	M	–	–
2905	V	–	4	5	A	M	–	–
2906	V	–	4	5	A	M	DVL	REM
2907	V	R	4	5	A	M	–	–
2908	V	R	4	5	A	M	DVL	REM
2909	V	R	4	5	A	M	BVL/DVL	REM
2910	V	–	4	5	A	M	BCC	REM
2911	V	–	4	5	A	M	BVL/DVL	REM
2912	V	–	5	1	A	F	–	–
2913	V	–	5	2	A	M	–	–
2914	V	–	5	3	A	M	–	–
2915	V	–	5	4	A	M	–	–
2916	V	–	5	5	A	M	–	–
2917	V	–	5	5	A	M	DVL	REM
2918	V	–	5	5	A	M	BVL/DVL	REM
2919	V	R	5	5	A	M	–	–
2920	V	R	5	5	A	M	DVL	REM
2921	V	–	5	5	A	M	BCC	REM
2922	V	R	5	5	A	M	BVL/DVL	REM

II

SPECIFICATIONS
MODEL 2917*

Function: Voltage measurement.

Ranges: As indicated by the RANGE control on the front panel, the instrument has five ranges. However, the manner in which values in each range are displayed is affected by the sampling period selected. The following table illustrates the several combinations of sampling time with the RANGE control set in each of its positions; in addition, the maximum over-range figures for each setting are given.

SAMPLE RATE	RANGE CONTROL SETTING	FULL-SCALE READING	MAX. OVER-RANGE READING FOR RATED ACCURACY
1 Second	0.1 V	99.999 MV	120.000 MV
	1.0 V	.99999 V	1.20000 V
	10 V	9.9999 V	12.0000 V
	100 V	99.999 V	120.000 V
	1000 V	999.99 V	1200.00 V
0.1 Second	0.1 V	.09999 V	0.12000 V
	1.0 V	0.9999 V	01.2000 V
	10 V	09.999 V	012.000 V
	100 V	099.99 V	0120.00 V
	1000 V	0999.9 V	01200.0 V
0.01 Second	0.1 V	0.0999 V	00.1200 V
	1.0 V	00.999 V	001.200 V
	10 V	009.00 V	0012.00 V
	100 V	0099.9 V	00120.0 V
	1000 V	00999. V	001200. V

Accuracy: On the 0.1V range.

Accuracy at 25°C: ±0.02% Rdg. ±0.01% F.S. ± 2 digits. Temperature effects: ±0.002% Rdg. per °C ±0.003% F.S. per °C.

On the 1, 10, 100, 1000V ranges.

Accuracy at 25°C: ±0.01% Rdg. ±0.005% F.S. ±1 digit. Temperature effects: ±0.001% Rdg. per °C ±0.0005% F.S. per °C.

Measurement Time: Sample period may be set at .01, or .1, or 1 second. As shown under Range, resolution decreases as speed increases.

Maximum Number of Measurements: 10 per second.

Common Mode Rejection: 120 db at 60 cps.
160 db with DC

(See Appendix for description of CMR test circuitry.)

*Although specifications are given for the Model 2917, they are applicable to all other 2900 models insofar as they possess the functions and capabilities given in the Table of Models in Section I, Introduction.

Input Resistance: 100K ohms on .1 volt
1 meg. on 1 volt
10 meg. on all higher ranges

Signal Mode Input Noise Rejection:
The integrating characteristic inherently averages out signal noise. Noise rejection varies with noise frequencies and sample period. AC noise attenuation is infinite for 1, 2, 3, etc. cps noise frequencies for a 1-second sample period; for 10, 20, 30, 40, etc. cps for 0.1 second period; and for 100, 200, 300 etc. cps for .01 second period.

The following table gives minimum noise rejection ratings at various frequencies for the three sample periods:

Sample Period	Noise Frequency CPS		CPS	CPS
	60–100	100–200	200–500	500-1000
1 Second	42–46 db	46–52 db	52–60 db	60–65 db
0.1 Second	22–26 db	26–32 db	32–40 db	40–46 db
0.01 Second	2 db	8 db	15 db	22 db

NOTE

The values set forth in the above table apply ONLY if the instantaneous input voltage does not exceed 120% of full scale at any time during the sample period.

Display Time: The readout display duration may be for ¼, ½, or 3 seconds before another scan is started when MODE switch is in RUN position.

Digital Readout (Print): Decimal voltage level. Levels are 0 V. for logic "1", –27 volt for Logic "0", 5 ma., max.

Ground Isolation: Inputs are completely floated and guarded. Up to 500 volts above chassis potential is allowable.

III

INSTALLATION AND OPERATION

1. UNPACKING

Instruments are shipped in two-piece polystyrene-bead containers. Cut the tape between container halves and open. If damage is seen, promptly notify the carrier. There is no packing material inside of the instrument. It is suggested that the container be saved if the instrument is to be shipped at a later date.

2. POWER SOURCE

The instrument is ready for operation from conventional 115-volt, 60-cycle power sources. A 220-volt source may be used if the two primaries of the power transformer are wired in series instead of in parallel. Schematic drawing at end of manual identifies the windings.

3. FUSING

The instrument is protected by a 3AG .6 ampere slo-blo fuse in an extractor post on the rear panel. Always use a fuse of the correct value.

4. POWER GROUNDING

The third pin on the power plug grounds the chassis of the instrument. The internal guard area is always isolated from ground. While general electrical practice requires that a chassis ground be provided to avoid shock hazard, the power-line ground, as such, is not related to the instrument's ability to provide accurate readings.

5. CABLES

The instrument is supplied with an input cable, Drawing No. 15004-126. The red pin is signal high; black is signal low; blue is guard shield. There is no connection to the chassis of the instrument. All inputs go directly inside of the guard shield area. When measuring a signal that should be shielded, the blue guard shield lead is used; at other times the black and blue leads may be tied together.

If the instrument is furnished with a printer, a printer cable is also supplied. The remote cable is available at extra cost. Connections to all cables are made at the rear of the instrument.

6. CONTROLS

The number and type of front-panel controls used is determined by the instrument's measuring capability. The controls described here are the Model 2917. If another model is being used, see the Table of Models given in the Introduction of this manual to determine applicability of the following description of controls.

Power Switch

The POWER switch has two positions — ON and OFF.
Although the instrument is ready to provide fairly accurate readings within 15 minutes, utmost accuracy is assured if a 30-minute warmup period is allowed.

Sample Period

This control is used to select the measurement time by internally determining the scanning rate of the instrument. When set at the REMOTE position, this function is controlled from a remote operation point connected to the instrument's remote cable. See schematic drawings for connection information.

Range

This control selects the range within which the input value falls. A certain amount of over-range is permissible (and a sixth digit will illuminate during over-range operation). See the Specifications, Section II, for specific range as related to each sample period. The REMOTE position on this control transfers this function to a remote operation point connected to the instrument's remote cable. See schematic drawings for connection information.

Display

This switch is used to select the readout display time before a new scan is initiated. The extreme counterclockwise position provides an image persistence of approximately ¼ to ½ second; the next position provides about one second; the last position provides about 3 seconds. Added to this switch at the clockwise end of travel is a spring-

6. CONTROLS (Continued)

return START position. This position is used when the instrument is in either STANDBY or in PRINT to initiate a new scan. The switch should be turned to this position for only a moment. The operation provided by this control is not available remotely.

Mode

One of the following three modes of operation may be selected:

RUN – At the end of display time, the instrument is internally started on a new scan and the instrument will continue to scan and display indefinitely.

STANDBY – After one scan the instrument will provide a display and stop operation until externally triggered to scan again, or until the display control is momentarily rotated to the START position.

PRINT – At the end of scan, the instrument will generate a negative 10-volt print pulse of 20 millisecond duration to operate a printer. The instrument will only scan again when a print command is issued by the associated printer. See schematic drawings for connection information.

IV

THEORY OF OPERATION

Basically, the instrument consists of two functional units, the converter unit which changes the given input voltage to frequency, and a reversible counter which counts the converter frequency (See Figure 4-1). There is no direct electrical connection between the converter and the counter units.

The Converter Unit

The heart of the converter is a highly stable, wideband chopper-stabilized differential amplifier, often called a Miller Integrator. Connected as shown, the amplifier generates an output whose rate of rise is directly and linearly (.01%) proportional to the input voltage. Two precision Schmitt triggers are connected to the output of the amplifier. One Schmitt trigger will fire at about 1.3 volt if the amplifier swings positively and the other will fire at 0.8 volt if the output voltage swings negatively. When the Schmitt trigger fires through the pulse-shaping network, a fixed amount of charge is delivered to the summing node of the amplifier to neutralize the input current. This action forces the summing node back to ground potential and the output of the amplifier is reset and another pulse is generated again. Since the slope (the rate of rise) of output voltage is linearly proportional to the input voltage for a given time, the frequency at which the Schmitt trigger is fired is also directly proportional (.01%) to the input voltage. Thus, DC voltage is converted to pulses whose rate of occurrence is an indication of the magnitude of the input voltage. If these pulses are counted, the number of pulses per unit time is an indirect measurement of the input voltage.

The monostables which follow the Schmitt triggers serve as buffer amplifiers. To provide high common-mode rejection, the output of the buffer amplifiers is fed into neon bulbs which emit light to activate photo cells (outside the converter box) whose outputs are used to trigger the counter amplifier. The technique is used to actuate the relays in the attenuator; this time, however, the control neon bulbs are located outside the converter and the photo-conductive cells (that control reed relays) are inside the converter box.

The Counter Unit

The pulses transmitted to the photocells are used to trigger the converter amplifiers. The counter then counts these amplified pulses whose numbers are indicated in the readout. Also, since the counter is reversible, the total count numerically represents the true integral of the input voltage.

From the foregoing description, it can be easily seen that the photo-electric coupling, plus the integrating property of the amplifier, lead to an extremely high-common mode level of rejection.

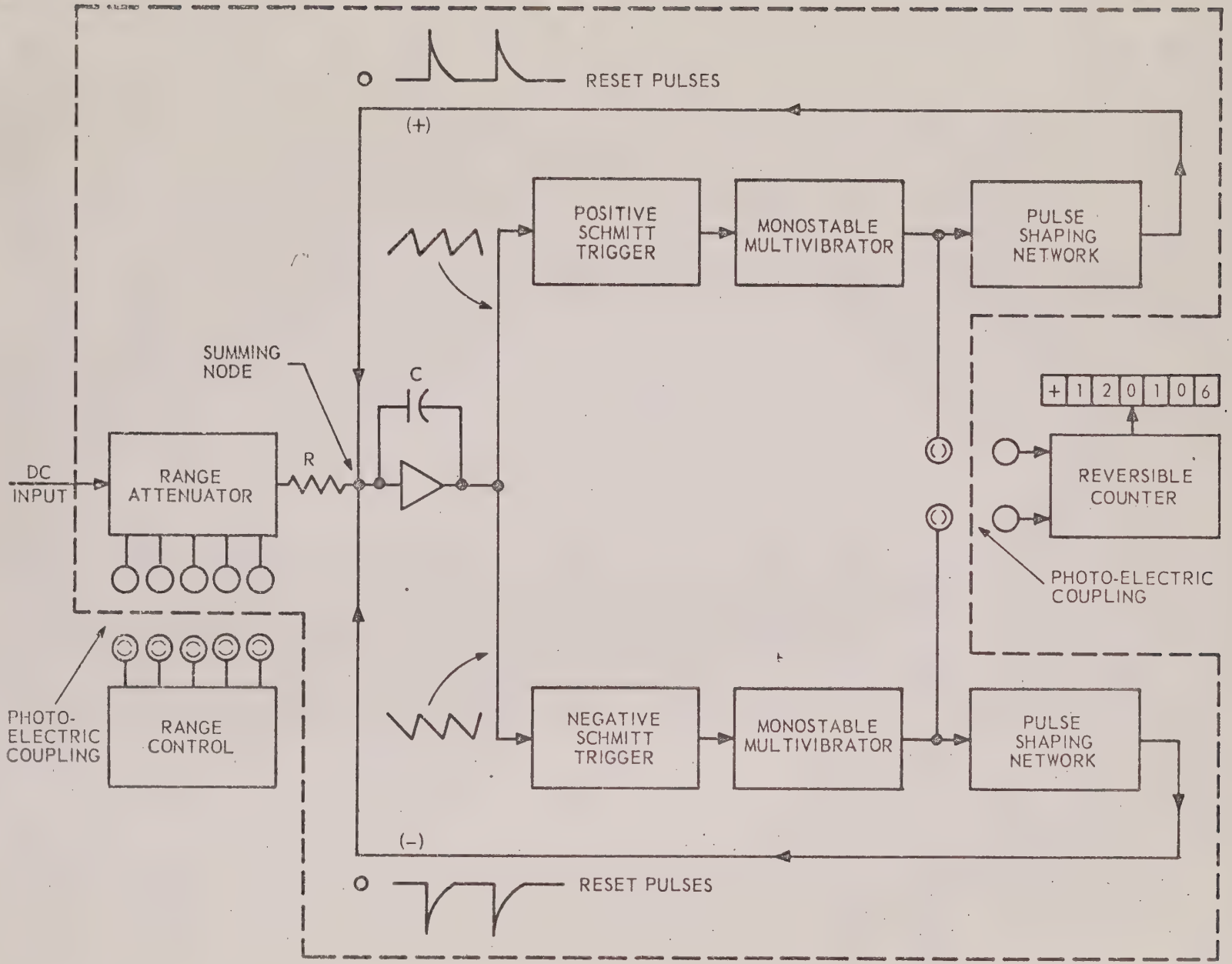


Figure 4-1. Functional Block Diagram. Components inside dotted line comprise the Converter Unit.

V

CALIBRATION

When a 2900 Series instrument is not providing readings within specifications, it is time for calibration, repair, or both. In the calibration information given in this section, it is assumed that the instrument is in good working order. The physical location of the several adjustments is shown in Figure 5-1. Follow all steps in the sequence listed.

CALIBRATION EQUIPMENT NEEDED

EMF Standard, such as NLS Model 3006. This EMF standard contains nine unsaturated cadmium standard cells connected in series, and provided with Superior Electric Five-way binding posts which are connected to each series junction to make available the voltage from each cell. The available voltages range from approximately 1.019 to 9.172. The Model 3006 is supplied with two calibration tables which indicate voltage values carried to six decimal places and accurate to .0.01%. One table gives the open-circuit EMF: the other table gives the output voltage values for a 10-megohm load. In addition, the tables give the cumulative voltage of the cells such as 1.01914, 2.03843, 3.05764, . . . 9.17724. These cells have been calibrated at the NLS Standards Laboratory with an NBS certified primary reference.

Stable, but not necessarily precisely known DC sources of .08-.1, .8-1, 8-10, 80-100, and 800-1000 volts. It is important that the top values for each voltage given not be exceeded; it is also necessary that a correct ratio, ± .01%, exist among these voltages. These ratios can be readily obtained by the use of a ratio box such as the NLS Model 3020. This NLS ratio box provides rapid and convenient switching facilities for fast, accurate calibration of digital voltmeters.

A frequency counter which can count to 100KC, accurate to ± 1 part.

PROCEDURE

NOTE

Before calibrating the instrument, the frequency of the crystal oscillator should be checked and, if necessary, adjusted as follows:

Place board P-25-P-26 on an extension board and connect the counter input to P26-6. With a non-metallic screwdriver adjust the clock frequency to provide exactly 100,000 cps.

1. Allow the instrument to warm up for 30 minutes with the top and bottom covers in place.

2. Set the RANGE switch at 10V; set the SAMPLE PERIOD at 1 SEC; set the MODE switch at RUN; set the DISPLAY full clockwise (do not engage the spring-return START position).

3. Connect the input cable to the instrument and short the three input leads together. Be certain that the leads are not placed near a hot soldering iron or other heat source.

4. Remove the top cover and adjust R–1 until the readout displays all zeroes.

5. Connect the input cable leads to the standard-cell bank. The red (signal high) lead is connected to the positive end of the standard-cell bank; the black and blue leads are connected to the negative end of the standard-cell bank. If electrical noise in the environment keeps the readout display from stabilizing, it will be necessary to connect the standard-cell cabinet to the negative polarity along with the blue and black leads.

6. The readout should display the numerical value given for the standard-cell bank; if it does not, adjust R–2 for agreement.

7. Reverse the polarity of the leads to the standard-cell bank, taking care to avoid placing even a momentary short upon the cells. The red lead connects to negative, black and blue to positive. If necessary (as in Step 5), connect the standard-cell case to one leg of the voltage source, but this time to the positive connection.

8. The readout should display the same numerical value obtained in Step 6. If the display is inaccurate, adjust R–3. This step completes the adjustment of the basic range of the instrument. Remove the standard cell-bank.

9. Connect the input cable leads to the stable source of 10 (8–10V) volts through the ratio box. Record the reading. Since the instrument has already been calibrated in this range, the reading noted here is the true voltage of the stable source.

10. Using the ratio box, switch the instrument RANGE switch to provide 1 (.8–1V) volt reading. Ignoring the decimal point, adjust R–5 so that the instrument provides the reading already recorded in Step 9.

11. Follow the procedure in Step 10, but apply .1 volt and set the instrument RANGE switch to .1V. Adjust R–4.

WARNING

The following two steps require the use of high voltage. Be careful!

12. Follow the procedure given in Step 10, but set the RANGE switch to 100 VOLTS and apply 100 volts. Adjust R–5.

13. Follow the procedure given in Step 10, but set the RANGE switch to 1000 VOLTS and apply 100 volts. Adjust R–7. This step completes the normal calibration procedure of the instrument. However, if there is a consistent and uniform error occuring in all ranges, it will be necessary to check the frequency adjustment as given in the Note preceding Step 1.

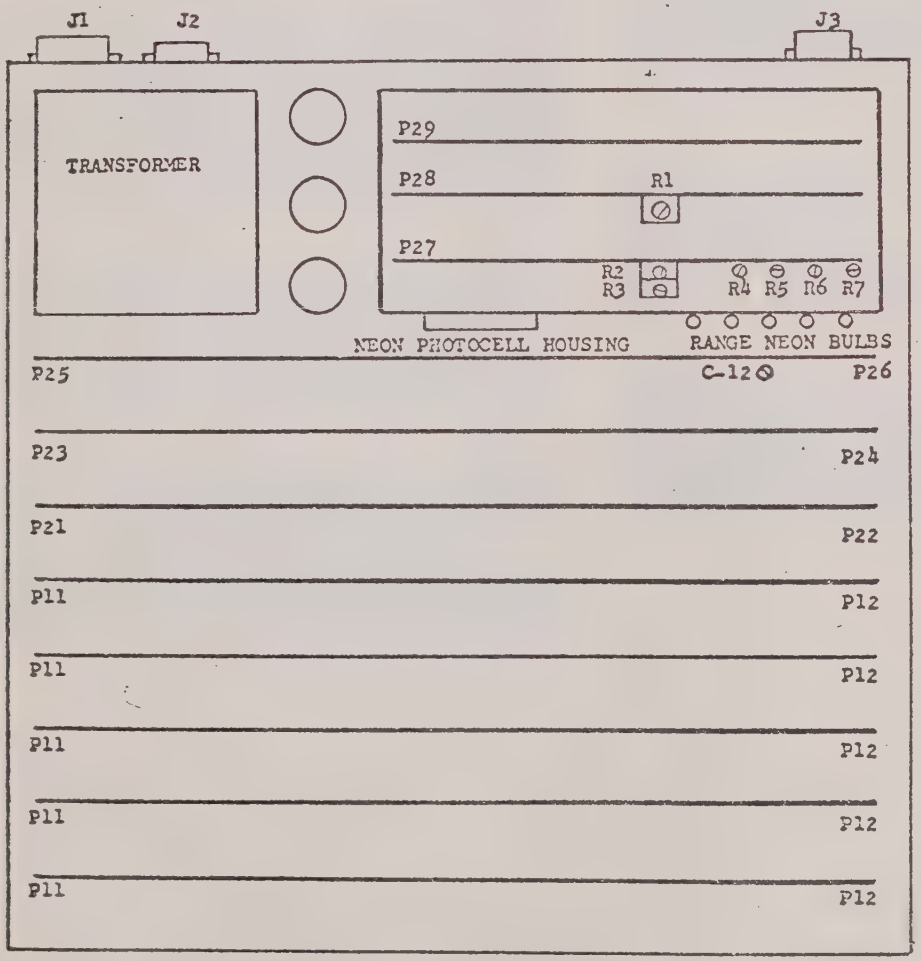
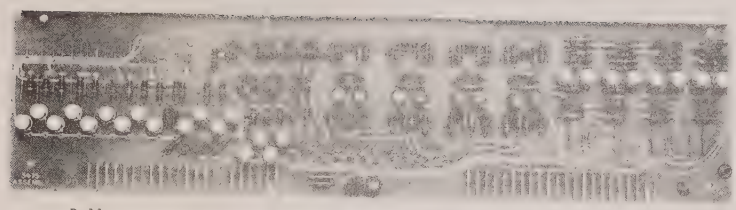


Figure 5-1. Top View of Digital Voltmeter with Cover Removed.

VI

MAINTENANCE



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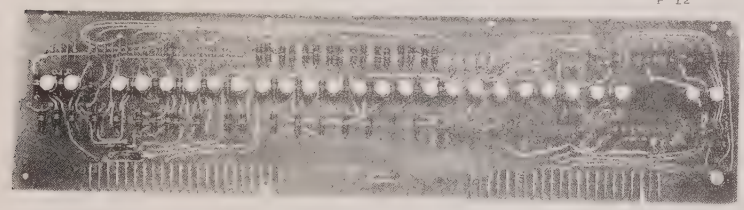

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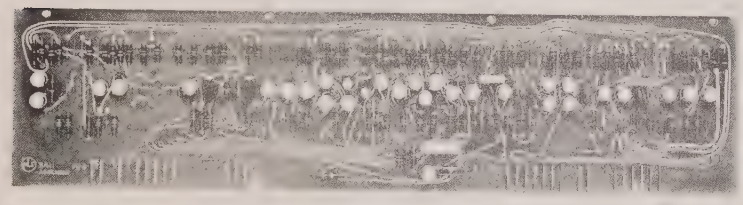

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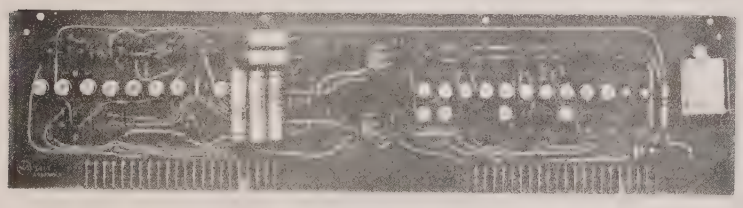

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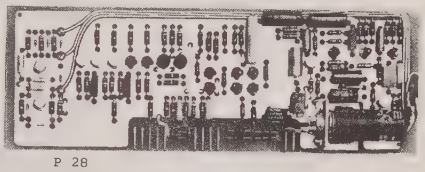

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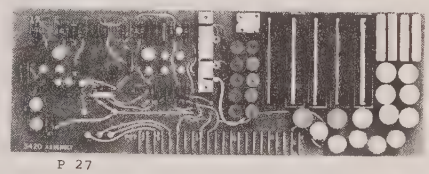


P 27

Circuit Board Description

P11–P12: Decade Board. The clock-counter and frequency decades are located on these five interchangeable boards.

P21–P22: Buffer Board. This board controls the neon bulbs for the range and range logic buffers.

P23–P24: Control Board. This board has the UP and DOWN gate, polarity flip-flop, and related timing monostables.

P25–P26: Oscillator Board. On this are located the clock frequency oscillator, input amplifier for the photo cell, −28, +90, +15, and +2 volts. The UP and DOWN pulse monostables directly feed the counter.

COUNTER

In trouble-shooting the instrument, the first step is to find out whether the trouble is in converter unit or in the counter unit. Once this is known, each unit can be independently repaired.

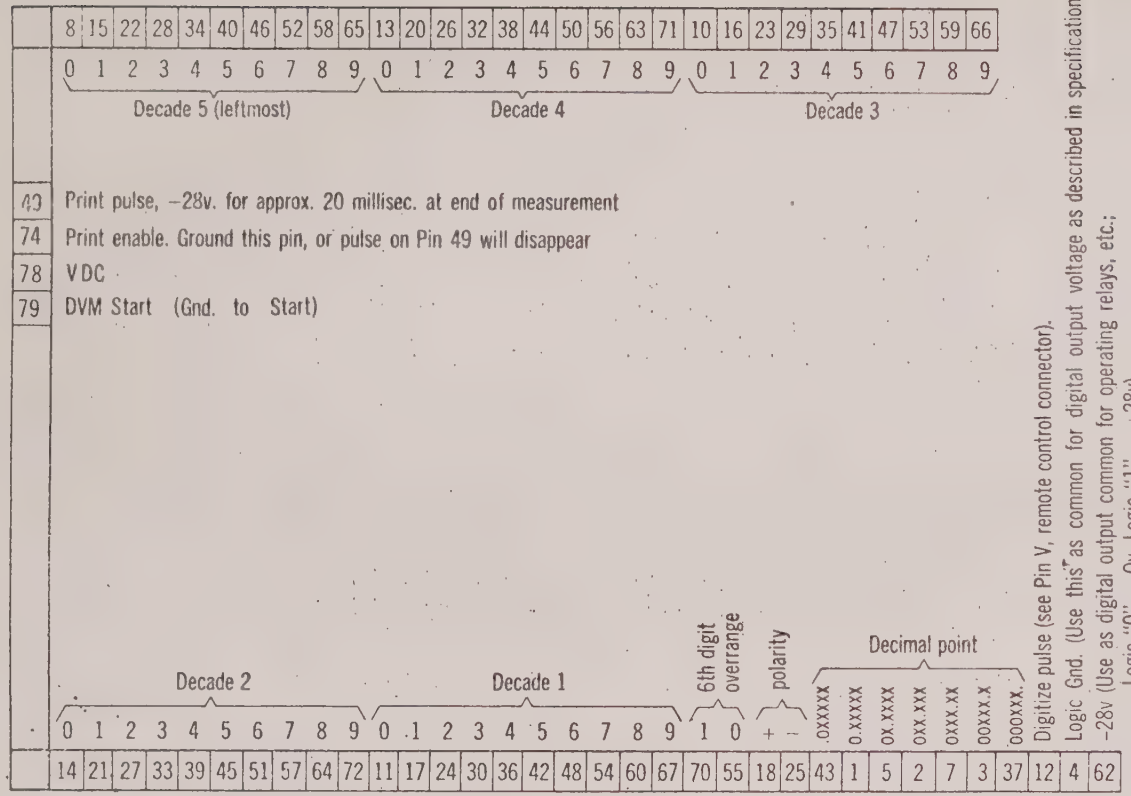
SYMPTOM	PROBABLE CAUSE	REMEDY
A. In RUN position, meter scans but gives all zero readings with inputs connected to source.	No Converter output	A–1. Connect positive voltage input of meter.
		A–2. Measure output pulses of photocell at J26-10 with a 1:10 probe. Pulse height should be 50 mv, 5 μs wide, minimum at 100 kc.
		A–3. If pulses are present with prescribed magnitude, converter is working properly. Otherwise, see trouble-shooting chart for converter.
	Counter faulty	A–4. If step 3 shows converter is giving the required pulse, proceed to check pulse at P26-8. Pulse should be about 10 volt. If true, proceed to step 5. Otherwise, look for defective parts in the pulse amplifier circuit.
		A–5. Check for pulses at P24-5. Pulse should be steady, 5 μs, 10 volt with no misfirings. If good, proceed to check pulses at P26-20. Good pulses at this point shows decade counter board is faulty. Proceed to step B3. Otherwise, look for defective parts in between.
B. Meter gives erroneous reading.	Converter gives false output.	B–1. Check the output of converter as in A–1, A–2, and A–3. If good, proceed to B–2.
	Decade boards faulty.	B–2. Check pulses at P24-5. Pulse should be 5 μs, 10 volt. If good, trouble is in decade boards. Proceed to B–3. Otherwise, look for defective parts in the gated one-shot.
		B–3. Change the decade counter boards (P11-P12) one by one until trouble is located.

SYMPTOM	PROBABLE CAUSE	REMEDY
C. Meter does not scan in RUN mode; readout on all the time; input has no effect on readings.	Counter faulty.	C–1. Replace control board (P23-P24).
D. Readout does not illuminate.	Open fuse.	D–1. Replace fuse.
E. One or two decades do not illuminate.	Burnt out readout lamps.	E–1. Interchange the decade board (P11-P12) in which the unlighted lamp is located. If the same lamp still does not light, it is open. Otherwise, proceed to E–2.
	Decade board (readout buffer) faulty	E–2. Replace decade board in question. Trouble is likely to be a defective buffer.
F. Two decimal points light at once.	Counter faulty	F–1. Check the buffer section of buffer board (P21–P22).
G. Meter does not range in one or two ranges.	Range neon bulb faulty	G–1. Rotate the RANGE control to see if the correct ranging neon bulb illuminates at each range setting. If the appropriate range light fails to illuminate, it is defective or the associated drive circuit is malfunctioning.
	Range relays faulty or photo-conductive cell faulty	G–2. Use a jumper to short out the photo-conductive cell associated with the malfunctioning range. If jumpering will cause the range to operate, the cell is defective. If the jumper has no effect, the range relay should be suspected of malfunction.

CONVERTER

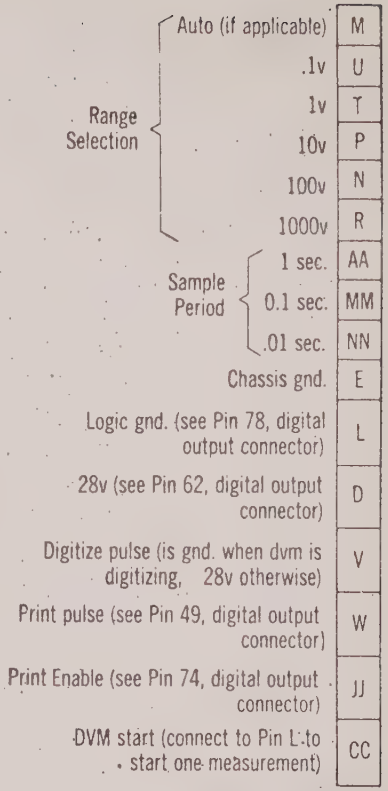
Cover the photo conductive cells in the attenuator with a strip of black tape. This will prevent external light source from actuating the range. Force the attenuator into the 10-volt range by shorting out the photo-conductive cell for the 10-volt range. Put the particular board to be checked on an extension board.

SYMPTOM	PROBABLE CAUSE	REMEDY
H. Output of amplifier stays at one voltage level; no reset pulses from resetter board.	Resetter board faulty	H–1. Replace resetter board. Check for burned transistor or opened capacitor for the channel concerned.
J. Resetter board putting out about 120 kc pulses but amplifier output (P28-18) sits on one voltage level.	Amplifier board faulty	J–1. Replace amplifier board.
K. Amplifier output (P28-18) produces positive and negative pulses at the same time.	Amplifier board faulty	K–1. Remove the resetter board (P28). Apply positive voltage to the meter. Amplifier output P-28-18 should swing to approximate negative, and swing to about 2 volts when input is negative. If above conditions are true, proceed to K–2. Otherwise, amplifier board is faulty.
	Resetter board faulty	K–2. Replace the resetter board.
L. Amplifier produces only one kind of pulse, either positive or negative on P28-18.	Resetter board faulty	L–1. Replace the resetter board. Check the NEGATIVE channel if positive pulses are produced. Check the POSITIVE channel if negative pulses are produced.


8 15 22 28 34 40 46 52 58 65 13 20 26 32 38 44 50 56 63 71 10 16 23 29 35 41 47 53 59 66
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
Decade 5 (leftmost)
Decade 4
Decade 3
49 Print pulse, −28v. for approx. 20 millisec. at end of measurement
74 Print enable. Ground this pin, or pulse on Pin 49 will disappear
78 VDC
79 DVM Start (Gnd. to Start)
Digitize pulse (see Pin V, remote control connector).
Logic Gnd. (Use this as common for digital output voltage as described in specifications.)
−28v (Use as digital output common for operating relays, etc.;
Logic "0" 0v, Logic "1" +28v)
Decade 2
Decade 1
6th digit overrange
polarity
Decimal point
0XXXXX
0.XXXX
0X.XXX
0XX.XX
0XXX.X
0XXXX.
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 1 0 + −
14 21 27 33 39 45 51 57 64 72 11 17 24 30 36 42 48 54 60 67 70 55 18 25 43 1 5 2 7 3 37 12 4 62

Amphenol Connector #201996-1 (male guide pin at Pin "2")

DIGITAL OUTPUT CONNECTIONS


Range Selection
Auto (if applicable) M
.1v U
1v T
10v P
100v N
1000v R
Sample Period
1 sec. AA
0.1 sec. MM
.01 sec. NN
Chassis gnd. E
Logic gnd. (see Pin 78, digital output connector) L
28v (see Pin 62, digital output connector) D
Digitize pulse (is gnd. when dvm is digitizing, 28v otherwise) V
Print pulse (see Pin 49, digital output connector) W
Print Enable (see Pin 74, digital output connector) JJ
DVM start (connect to Pin L to start one measurement) CC

Connector is Amphenol 201985-1
(male guide pin at A)

REMOTE CONTROL CONNECTOR

NON-LINEAR SYSTEMS, INC.
Del Mar, California

CALCULATING THE MAXIMUM ERROR CAUSED BY RIPPLE ON THE INPUT OF AN INTEGRATING DIGITAL VOLTMETER

One advantage of integrating dvms is that, without using input filters, they completely reject sinusoidal ac ripple superimposed on the dc voltage being measured, provided that an integral number of noise cycles occur during the dvm's sample period. This is because the integrated value of a sine wave is zero. They'll also completely reject any ripple waveforms other than sinusoidal if the area (volt-seconds) of the positive polarity section of the ripple waveform is equal to the waveform's negative polarity area. The maximum measurement error caused by ripple occurs when the ripple frequency is such that instead of an integral number of cycles of ripple occurring during the dvm sampling period, an extra half cycle of ripple gets through. (Fig. 1).

This maximum error is calculated by determining how many volt-seconds (area FEC in Fig. 1) the extra half cycle of ripple adds to the volt-seconds created by the dc signal (area ABCD in Fig. 1). The area FEC (in volt-seconds) is the average ripple voltage (rms value ÷ 1.11) multiplied by one-half the ripple waveform period. Area ABCD is found by multiplying the dc amplitude by the dvm sample period. The % error is then 100 times the ratio of area FEC to ABCD or:

$$\% \text{ error} = \frac{\dfrac{\text{rms ripple amplitude}}{1.11} \times \dfrac{\text{ripple period}}{2}}{\text{DC amplitude} \times \text{DVM sample period}} \times 100$$

Example: What error is caused by 0.3 volts rms of 100.5 cps sine wave ripple superimposed on a 20 volt dc signal, using a 1 second dvm sample period?

$$\% \text{ error} = \frac{\dfrac{.3}{1.11} \times \dfrac{1}{100.5 \times 2}}{20 \times 1} \times 100 = 0.00667\%$$

Thus, only .00667% error was caused by a ripple voltage whose peak value is 2.1% that of the dc voltage being measured. Note that this is an extreme case since ripple frequencies usually encountered are not odd values like 100.5 cps, but are whole number values (50, 60, 400, or integral multiples of these), and ripple of such frequencies would be completely rejected.

Ripple-caused error decreases if dvm sampling period is increased, or if ripple frequency increases. For example, the error caused by a

0.3 v rms 10.0005 kc ripple signal on a 20 v. dc signal measured with a 1 second dvm sample period would be 0.000065% of reading.

If the ripple is so great as to cross the zero axis (Fig. 2), some integrating dvms will add the negative area (area below zero axis) to the positive area, and will display the last polarity encountered (in this case, negative). This results in highly erroneous measurement, and makes the instrument virtually useless for measuring low voltages in the presence of noise. NLS integrating dvms are unique in this regard, since they have a bidirectional counter and therefore give the true integral (subtracting the negative area from the positive) and give the correct polarity sign. Furthermore, NLS integrating dvms do not accumulate one digit of zero crossing error each time the input crosses the zero axis.

For more detailed discussion on this, refer to the mimeographed NLS bulletin titled "Integrating Digital Voltmeters (Voltage-To-Frequency Conversion Type)."

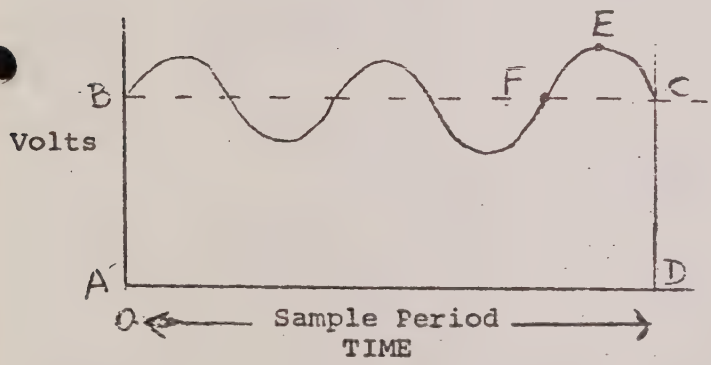


Figure I

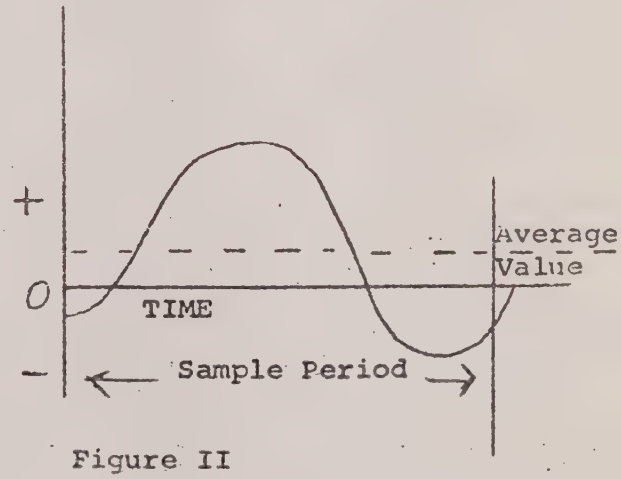


Figure II

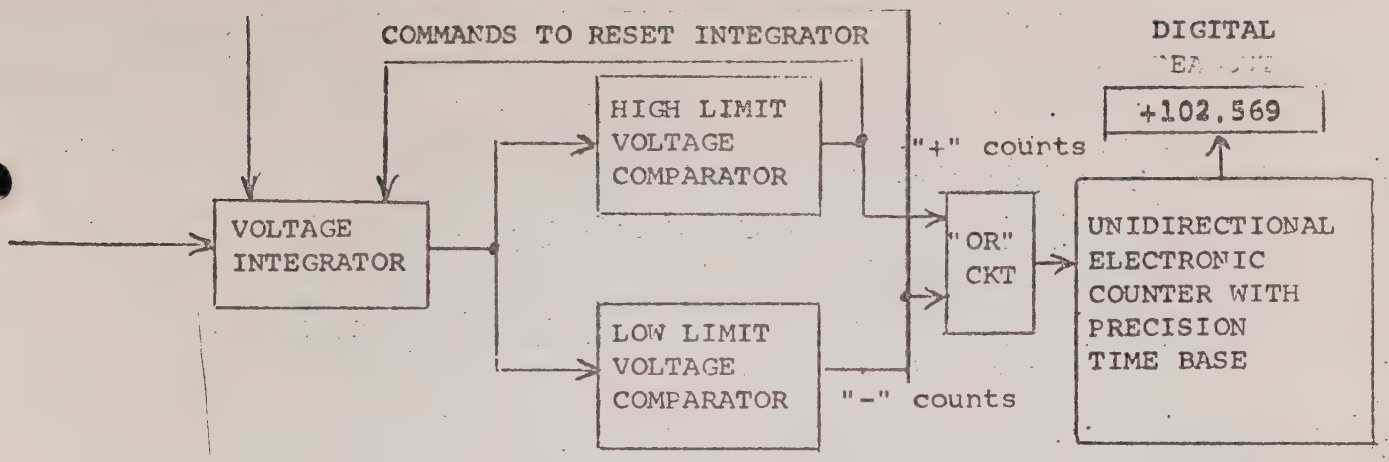


FIGURE 1. AN INTEGRATING DVM THAT WILL NOT PROPERLY AVERAGE OR INTEGRATE INPUTS THAT CHANGE POLARITY DURING THE SAMPLE PERIOD.

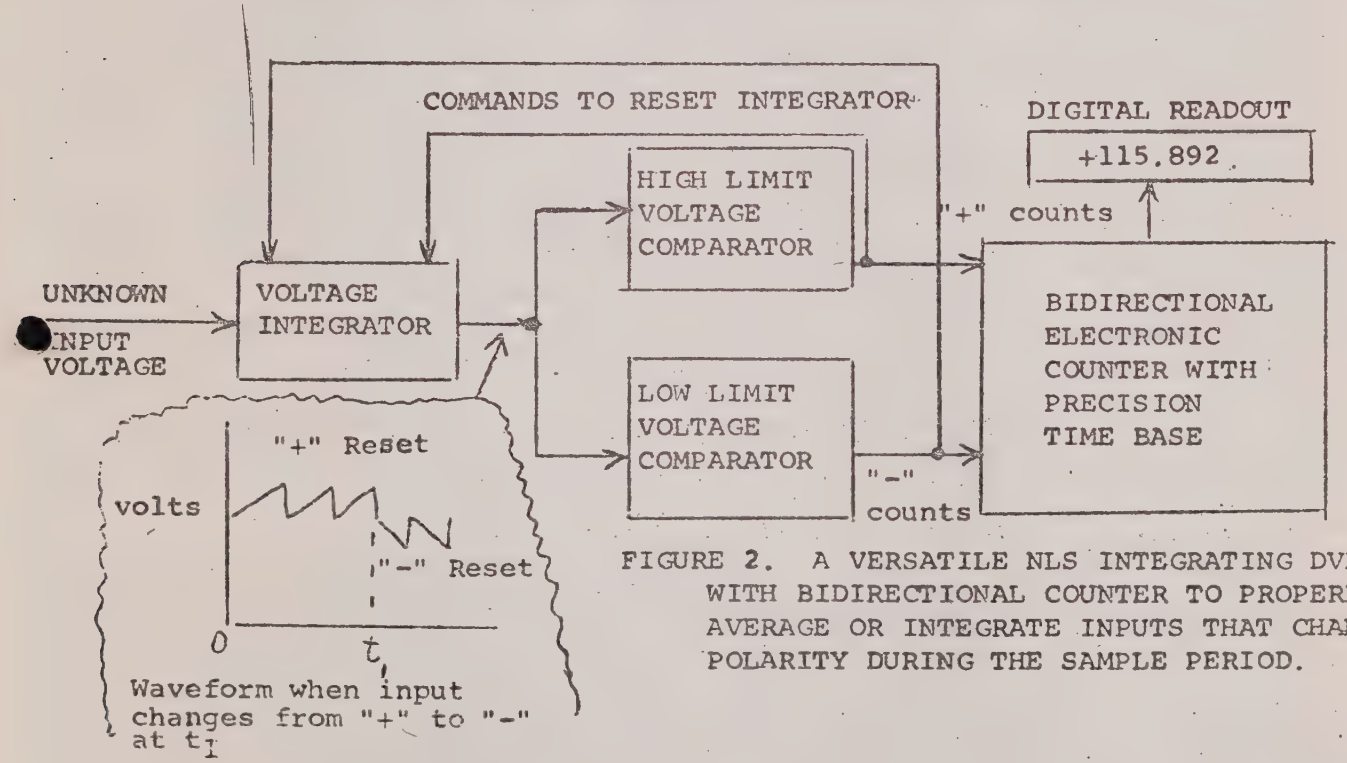


FIGURE 2. A VERSATILE NLS INTEGRATING DVM WITH BIDIRECTIONAL COUNTER TO PROPERLY AVERAGE OR INTEGRATE INPUTS THAT CHANGE POLARITY DURING THE SAMPLE PERIOD.

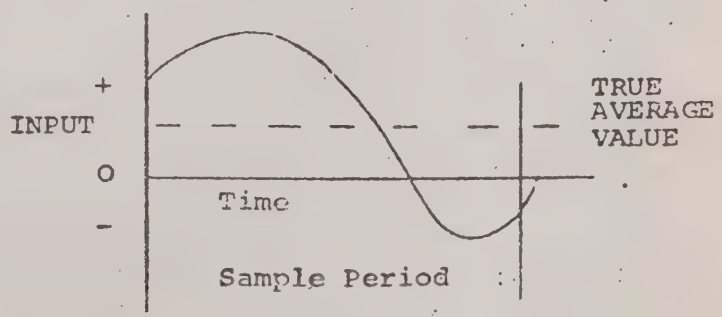


FIGURE 3. THE DVM OF FIG. 1 DISPLAYS A "-" SIGN WHEN READING THE INPUT SHOWN HERE. ALSO, IT ADDS THE AVERAGE VALUE OF THE POSITIVE PORTION TO THE AVERAGE VALUE OF THE NEGATIVE PORTION, THUS GIVING A HIGH READING. THE NLS DVM OF FIG. 2 GIVES THE TRUE AVERAGE VALUE.

INTEGRATING DIGITAL VOLTMETERS
(Voltage-To-Frequency Conversion Type)

In these instruments the unknown input voltage is converted to a pulse train whose repetition rate is directly proportional to the input voltage magnitude. The total number of pulses generated over an accurately clocked 1 second interval is counted electronically and displayed as the voltage value.

In a typical instrument, an input of 100 millivolts would create 100,000 pulses in one second, and this would be displayed as 100.000 volts. If the input voltage changes during the measuring interval, the pulse repetition rate changes proportionately, and the total number of pulses that occur during the 1 second sample period is a measure of the number of volt-seconds at the input. Therefore, these instruments effectively mathematically integrate the input voltage. Thus, for example, they are useful for obtaining velocity from a voltage which is proportional to acceleration. Another advantage of these instruments is their inherent ability to reject sinusoidal ripple. This ability stems from the integrating characteristic of the instrument, and the fact that the integrated value of an integral number of sine waves is zero. Therefore, if an integral number of sine wave noise occurs during the one second sampling interval, their contribution to the over-all readout is "integrated out."* Sampling times of 1 second, .1 second and .01 seconds are usually supplied in integrating dvms. At the 1 second and .1 second intervals, 60 cycle or 400 cycle noise would be virtually completely rejected. On the .01 second sampling period, an entire 60 cycle sine wave would not occur, and 60 cycle noise would produce some inaccuracy in measurement; however, 400 cps noise would be rejected.

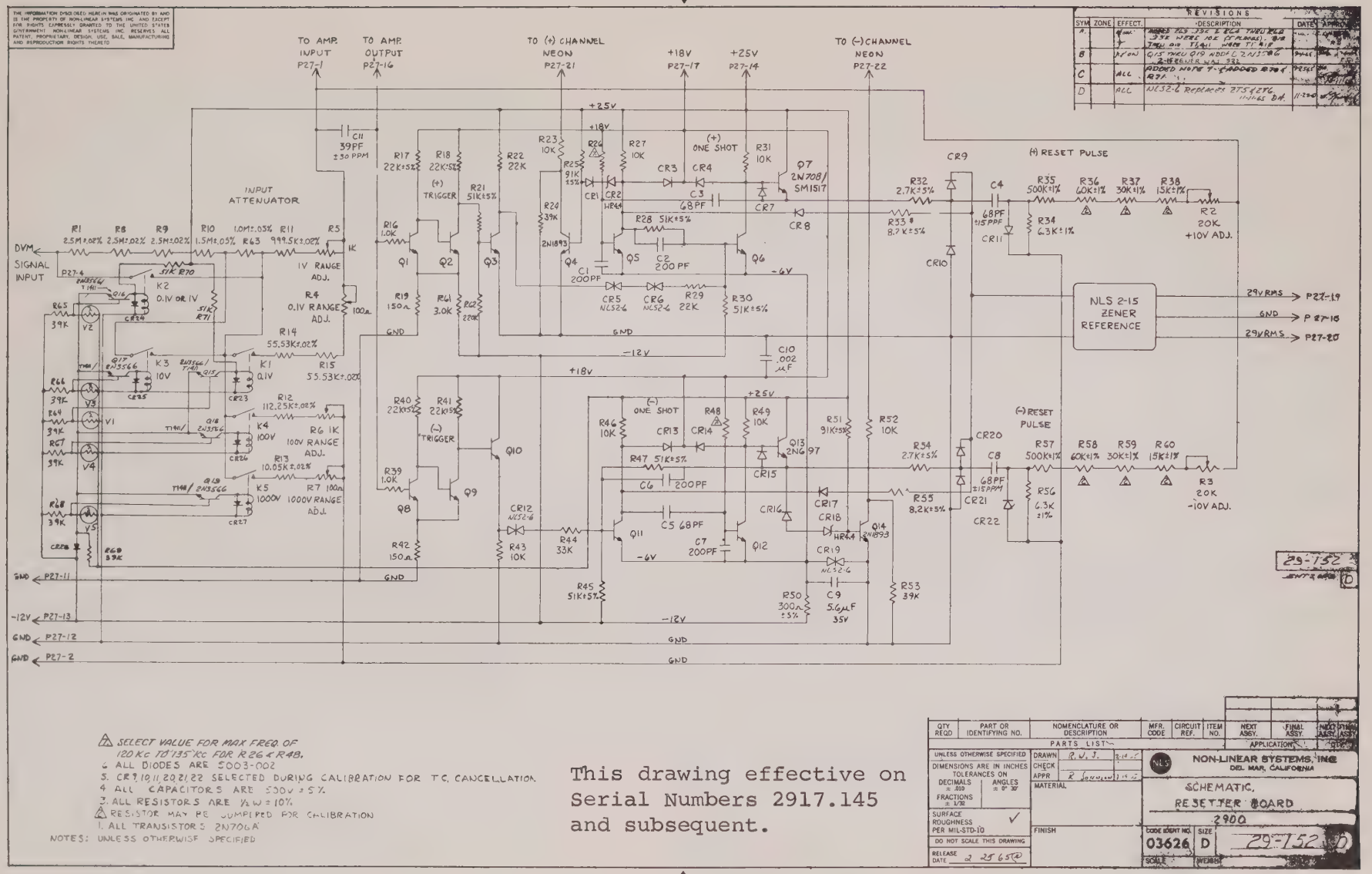
The basic functional diagrams of integrating dvms are shown in Fig. 1 and 2. The unknown input voltage is applied to an integrating circuit whose output is a ramp function whose slope is proportional to input amplitude. This ramp is fed to a voltage comparator which will, at some accurately fixed voltage value, reset the integrator to zero volts instantaneously; whereafter the integrated output will again start climbing toward the voltage comparator's limit value. Thus, a sawtooth function is generated whose frequency is proportional to input voltage. Typically, such an integrator would produce an output which would reach the reset limit at the end of 1 second with a 1 microvolt input, and the lowest range of a digital voltmeter of this type would produce 1 count at the end of 1 second with 1 microvolt input. Full scale on this low range would be 99.999 millivolts, which would produce a frequency of 99,999 cycles per second. Some integrating dvms use voltage controlled oscillators different than the one described above, but the over-all dvm principle is the same. Additional ranges are obtained by attenuating the input voltage in decade steps.

(*) Integrating gives the time - average value of the input voltage in the same way that we obtain average velocity by dividing distance traveled in a given time by the elapsed time.

Although most integrating digital voltmeters available today are of the type shown in Fig. 1, they have serious difficulties which are eliminated by the bi-directional integrating dvm of the type built by Non-Linear Systems, Inc., and shown in Fig. 2. In Fig. 1, changing the input voltage polarity does not cause the counter to count backwards. Therefore, when using the instrument for mathematical integration, the integral of the absolute value of the input is displayed, without regard to sign. For example, if an ac sine wave is applied, the dvm of Fig. 1. reads twice the area under one-half the sine wave, whereas the Non-Linear Systems bi-directional integrating dvm of Fig. 2 reads the true integrated value of a sine wave, which is zero (of course, the dvm of Fig. 2 could be modified to operate the same as the one in Fig. 1, if required). Another item to check in integrating dvms is the necessity for periodic recalibration of the integrator reset circuits of Fig. 1 and 2. In some cases, the blocking oscillators used as resetters must be manually recalibrated from hour to hour against a built-in standard, to obtain full specified accuracy, while NLS integrating dvms have intrinsically stable resetting circuits that do not require periodic adjustment. Furthermore, the polarity sign of the dvm in Fig. 1 will be the polarity that the input signal had at the instant the sampling period ended; even if the input signal was predominately positive, a negative sign is likely to be displayed in the readout (see Fig. 3). In the Non-Linear Systems' bi-directional dvm of Fig. 2, however, the bi-directional counter counts forward when the input signal polarity is positive and counts backwards for negative inputs. Thereby, it gives a true mathematical integral, and its polarity sign represents the true polarity of the input average value, even when the input voltage passes through the zero axis during measurement.

Some integrating dvms have a zero crossing error which can cause several digits error each time the input waveform goes through zero volts. Therefore, if one is attempting to measure a small dc voltage which has enough sinusoidal ripple to cause voltage excursions through zero value (as in Fig. 3), large errors can occur, and such dvms are therefore not accurate "null meters." The design of NLS integrating dvms eliminate this zero crossing error.

An advantage of the integrating dvm which has heretofore been almost completely ignored is encountered when measuring varying voltages to which statistical analysis must later be applied. If such voltages are measured with a tracking logic or scan logic potentiometric dvm, the numerals obtained will be biased toward 9's (e.g., 1.119, 1.129 or 1.199, 1.299, etc.) when increasing voltages are measured, and toward 0's for decreasing voltages. Integrating dvms do not have this numerical bias.



REVISIONS

SYM	ZONE	EFFECT	DESCRIPTION	DATE	APPR
A			ADDED NLS 33Z & DCA THRU DCD -33Z WERE 10Z IF ALREADY DID THRU Q19 WERE T1 N1P		
B			Q13 THRU Q19 WERE 2N3566 2-15 ZENER WAS 33Z		
C	ALL		ADDED NOTE 7 - ADDED R70		
D	ALL		NLS2-6 Replaces 27S/28G	11-22-65	DA

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△ SELECT VALUE FOR MAX FREQ OF 120 Kc TO 135 Kc FOR R26 & R48.
6. ALL DIODES ARE 5003-002
5. CR9,10,11,20,21,22 SELECTED DURING CALIBRATION FOR T.C. CANCELLATION
4. ALL CAPACITORS ARE 500V ± 5%
3. ALL RESISTORS ARE ½ W ± 10%
△ RESISTOR MAY BE JUMPERED FOR CALIBRATION
1. ALL TRANSISTORS 2N706A

NOTES: UNLESS OTHERWISE SPECIFIED

This drawing effective on Serial Numbers 2917.145 and subsequent.

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.	NEXT ASSY.	FINAL ASSY.	ASSY.

PARTS LIST — APPLICATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010 ANGLES ± 0° 30'
FRACTIONS ± 1/32
SURFACE ROUGHNESS PER MIL-STD-10
DO NOT SCALE THIS DRAWING
RELEASE DATE 2 25 65

DRAWN R.V.J. 2-19-65
CHECK
APPR R. [illegible] 2-19-65
MATERIAL
FINISH

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

SCHEMATIC,
RESETTER BOARD
2900

CODE IDENT NO. 03626 SIZE D
29-752 D
SCALE WEIGHT

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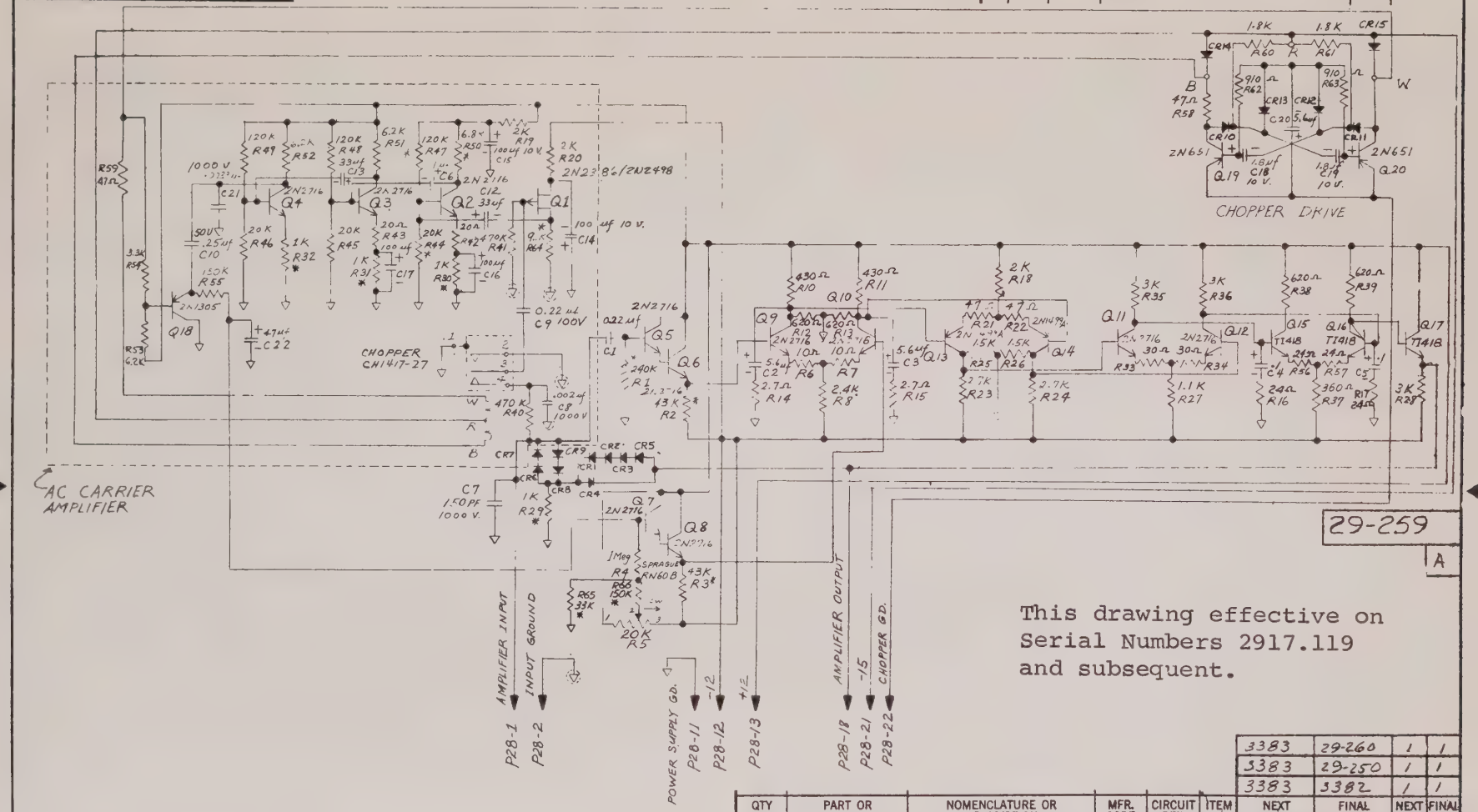
REVISIONS					
SYM	ZONE	EFFECT.	DESCRIPTION	DATE	APPROVED
A		ALL	CHANGED 2N3635 TO 2N3565. ADDED ALT. FOR Q1, INCORP. ECR 1	7-7-65	RJ



29-259

A

This drawing effective on Serial Numbers 2917.119 and subsequent.

3383	29-260	1	1
3383	29-250	1	1
3383	3382	1	1

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.	NEXT ASSY.	FINAL ASSY.	NEXT ASSY.	FINAL ASSY.
PARTS LIST						APPLICATION		QTY.	

4. 2N3565 IS AN ALTERNATE FOR 2N2716 (Q2 THRU Q12), 2N3565 IS AN ALTERNATE FOR TI418 (Q15, 16 & 17).
3. C1, C4 & C5 ARE 100 VOLTS, C2, C3, C12, C13 & C20 ARE 10 VOLTS, C16 & C17 ARE 3 VOLTS.
2. ALL RESISTORS ARE 1/2 WATT, 5%, AB EXCEPT THOSE MARKED WITH ASTERISK (*) ARE CORNING C-20.
1. DIODES D6 THRU D9 ARE IN458, ALL OTHERS ARE TYPE UG-315 (5003-002)

NOTES: UNLESS OTHERWISE SPECIFIED:

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010
ANGLES ± 0° 30'
FRACTIONS ± 1/32
SURFACE ROUGHNESS PER MIL-STD-10 ✓
DO NOT SCALE THIS DRAWING
RELEASE DATE 8-4-65@

DRAWN	Hanrahan	7-7-65
CHECK	Knuth	
APPR	RJT	7-8-65

MATERIAL

FINISH

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

SCHEMATIC, AMPLIFIER BOARD —

SERIES 2900 - MODEL 2917A

CODE IDENT NO.	SIZE		REV.
03626	C	29-259	A

SCALE ____ WEIGHT ____ SHEET 2 of 3

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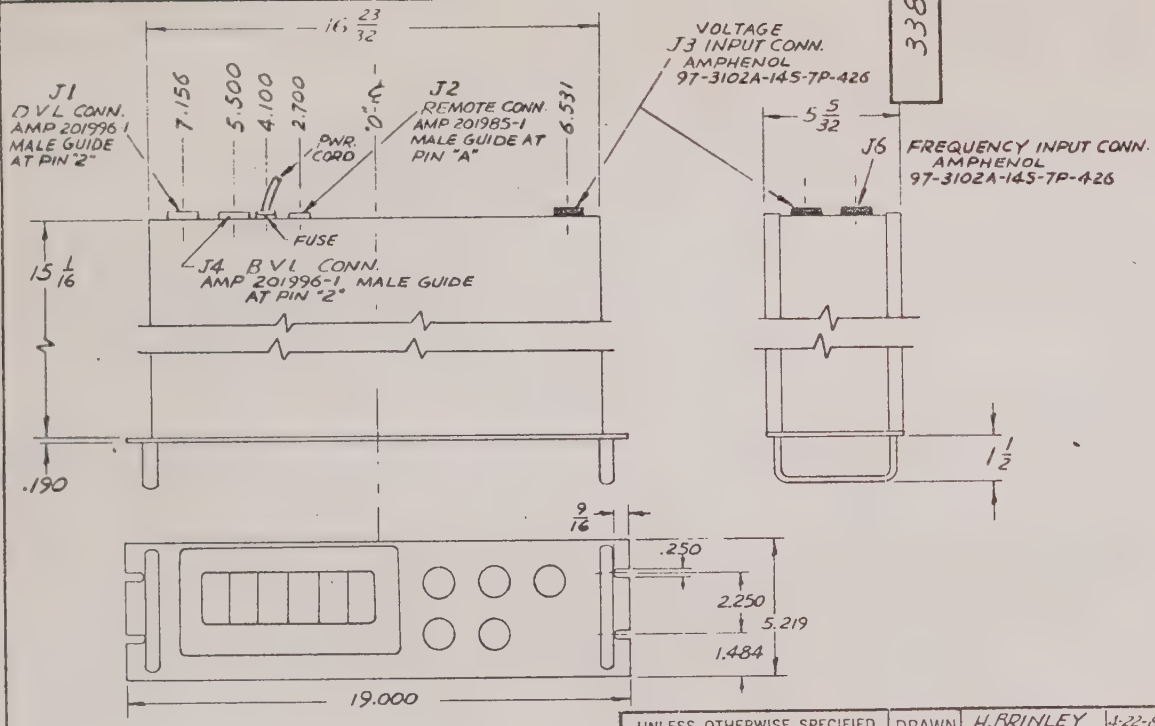
3382 SHT. 3

REVISIONS

SYM	ZONE	EFFECT.	DESCRIPTION	DATE	APPROVED
A		29.73	RELOCATED CONNECTORS J1, J2 & J3. ADDED CONNECTORS J4 & J6.	4-22-64	11-16-64 R.L.J



NEXT ASSY.	FINAL ASSY.	NEXT ASSY.	FINAL ASSY.
APPLICATION		QTY.	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010
ANGLES ± 0° 30'
FRACTIONS ± 1/32
SURFACE ROUGHNESS PER MIL-STD-10 ✓
DO NOT SCALE THIS DRAWING
RELEASE DATE

DRAWN	H. BRINLEY	4-22-64
CHECK		
APPR	R. L. J	4-22-64

MATERIAL

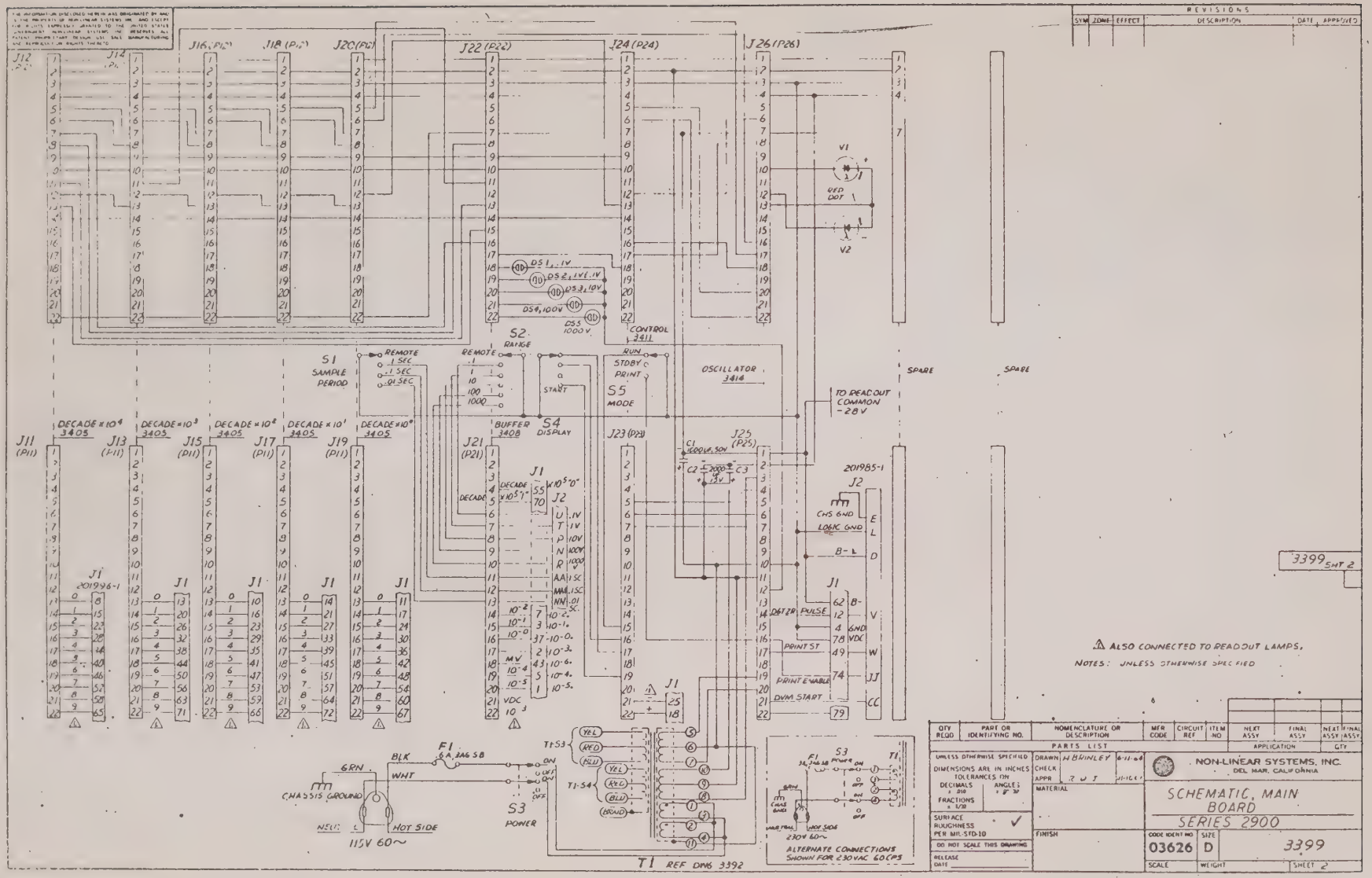
FINISH

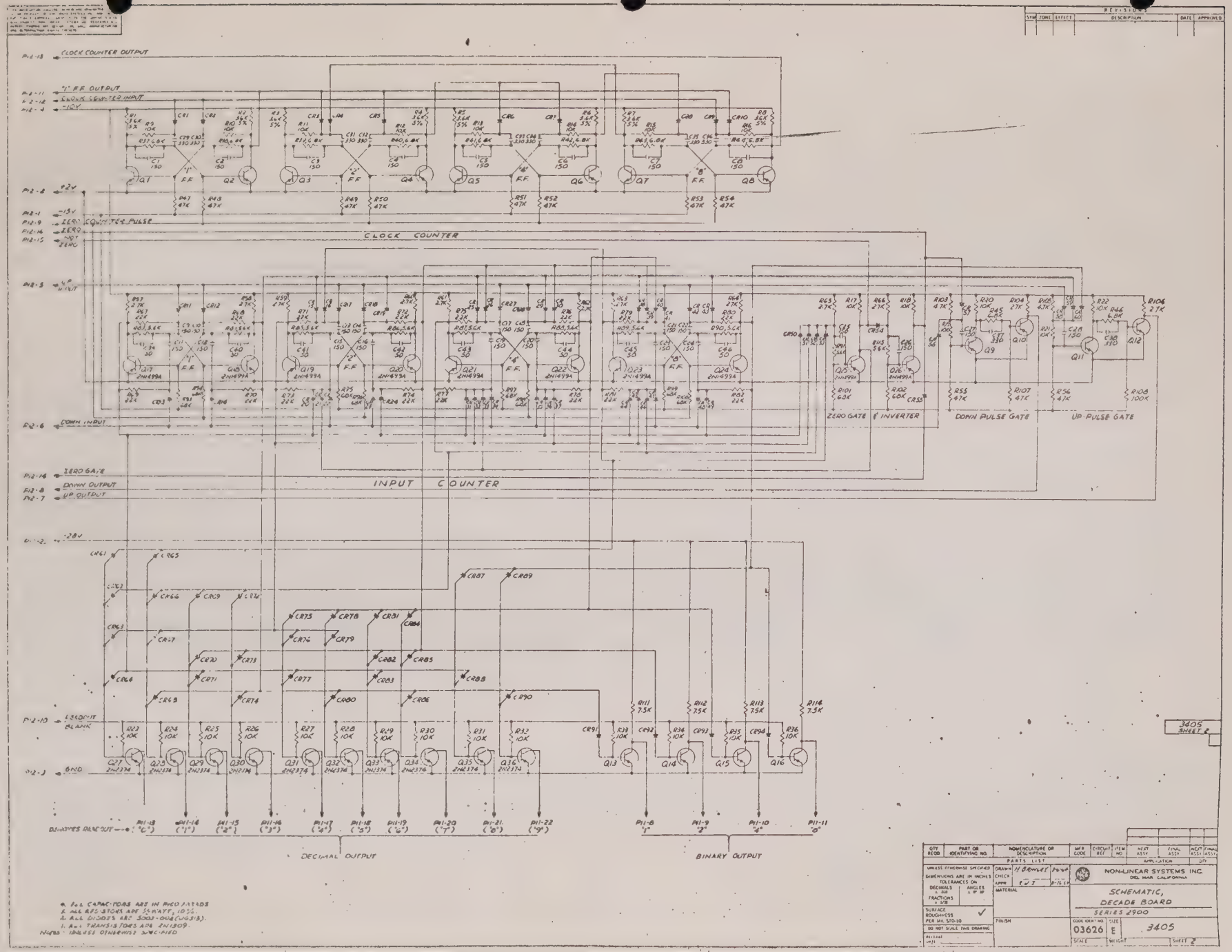
NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

DIGITAL VOLTMETER - OUTLINE DRAWING

SERIES 2900

CODE IDENT NO.	SIZE	
03626	B	3382
SCALE 1/4	WEIGHT	SHEET 3

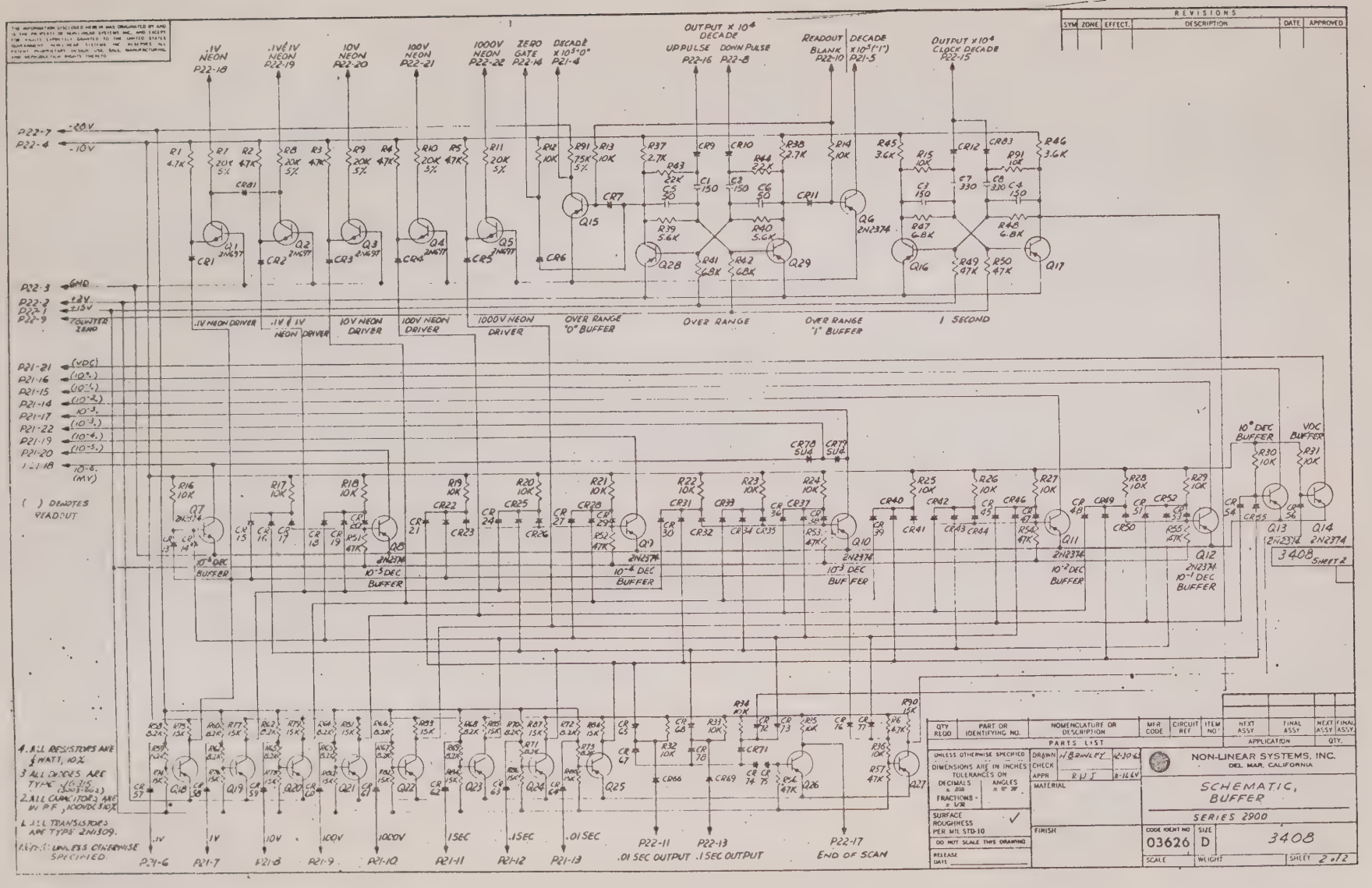

REVISIONS
SYM ZONE EFFECT DESCRIPTION DATE APPROVED
J12 (P12)
J16 (P16)
J18 (P18)
J20 (P20)
J22 (P22)
J24 (P24)
J26 (P26)
S1 SAMPLE PERIOD
REMOTE
1 SEC
.1 SEC
.01 SEC
S2 RANGE
1
10
100
1000
BUFFER 3408
S4 DISPLAY
START
S5 MODE
RUN
STDBY
PRINT
OSCILLATOR 3414
CONTROL 3411
DS1, 1V
DS2, 1V
DS3, 10V
DS4, 100V
DS5 1000V
V1
NEON LAMP
V2
SPARE
SPARE
TO READOUT COMMON -28V
DECADE x10^4 3405
DECADE x10^3 3405
DECADE x10^2 3405
DECADE x10^1 3405
DECADE x10^0 3405
J11 (P11)
J13 (P11)
J15 (P11)
J17 (P11)
J19 (P11)
J21 (P21)
J23 (P23)
J25 (P25)
C1 1000μf, 50V
C2 2000μf 12V
C3
201985-1
J2
CHS GND
LOGIC GND
B-L
E
L
D
J1
201998-1
DATA
PULSE
PRINT ST
PRINTABLE
DVM START
62
12
4
78
49
74
79
B-
V
GND
VDC
W
JJ
CC
⚠ ALSO CONNECTED TO READOUT LAMPS.
NOTES: UNLESS OTHERWISE SPECIFIED
3399 SHT 2
F1 6A, 3AG SB
GRN
BLK
WHT
CHASSIS GROUND
NEUT
HOT SIDE
115V 60~
S3 POWER
ON
OFF
T1 S3
T1 S4
YEL
RED
BLU
BRN
T1 REF DWG 3392
S3
F1 3A, 3AG SB
POWER ON OFF
CABLE CLAMP
NEUTRAL
HOT SIDE
230V 60~
ALTERNATE CONNECTIONS SHOWN FOR 230VAC 60CPS
QTY REQD
PART OR IDENTIFYING NO.
NOMENCLATURE OR DESCRIPTION
MFR CODE
CIRCUIT REF
ITEM NO
NEXT ASSY
FINAL ASSY
PARTS LIST
APPLICATION
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010
ANGLES ± 0° 30'
FRACTIONS ± 1/32
SURFACE ROUGHNESS PER MIL-STD-10
DO NOT SCALE THIS DRAWING
RELEASE DATE
DRAWN N.B.WINLEY 6-11-64
CHECK
APPR J.W.J 11-16-64
MATERIAL
FINISH
NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA
SCHEMATIC, MAIN BOARD
SERIES 2900
CODE IDENT NO 03626
SIZE D
3399
SCALE
WEIGHT
SHEET 2

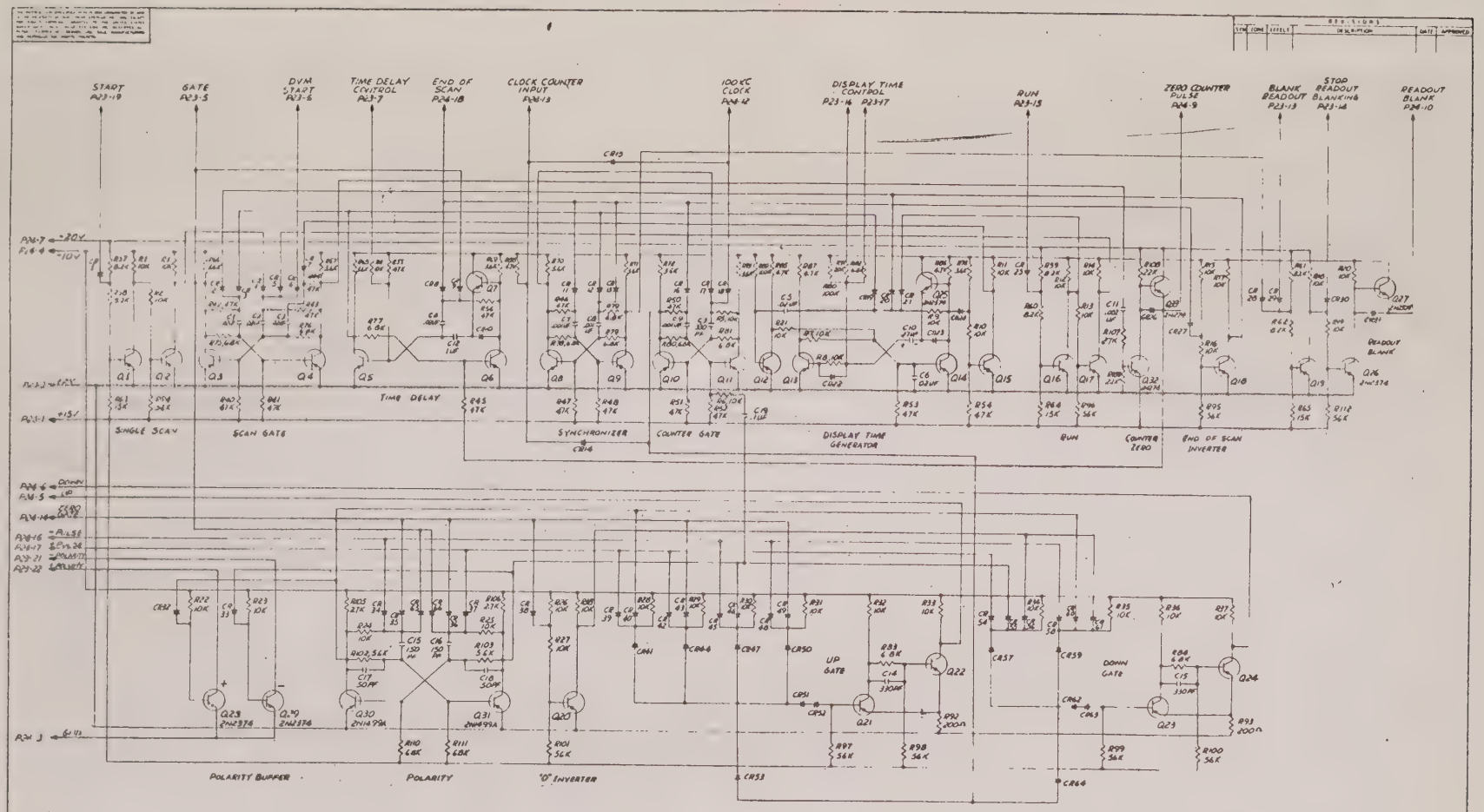


QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR CODE	CIRCUIT REF	ITEM NO	NEXT ASSY	FINAL ASSY	NEXT FINAL ASSY
		PARTS LIST				APPLICATION		

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON DECIMALS ± .010 FRACTIONS ± 1/16 ANGLES ± 0° 30'	DRAWN H. BARKLEY 8-16-64	NON-LINEAR SYSTEMS INC. DEL MAR CALIFORNIA	
	CHECK	SCHEMATIC, DECADE BOARD	
	APPR. R.V.T. 8-16-64	SERIES 2900	
	MATERIAL		
SURFACE ROUGHNESS PER MIL STD-10 ✓	FINISH	CODE IDENT NO. 03626	SIZE E
DO NOT SCALE THIS DRAWING		SCALE	WEIGHT
			SHEET 2

3405 SHEET 2


.1V NEON P22-18
.1V/1V NEON P22-19
10V NEON P22-20
100V NEON P22-21
1000V NEON P22-22
ZERO GATE P22-16
DECADE X10^-0 P21-4
OUTPUT X 10^4 DECADE UP PULSE P22-16
DOWN PULSE P22-8
READOUT BLANK P22-10
DECADE X10^-3 (1") P21-5
OUTPUT X10^4 CLOCK DECADE P22-15
P22-7 +20V
P22-4 -10V
P22-3 GND
P22-2 +8V
P22-1 +15V
P22-9 TO WITTER ZERO
.1V NEON DRIVER
.1V / 1V NEON DRIVER
10V NEON DRIVER
100V NEON DRIVER
1000V NEON DRIVER
OVER RANGE "0" BUFFER
OVER RANGE
OVER RANGE "1" BUFFER
1 SECOND
P21-21 (VDC)
P21-16 (10^0)
P21-15 (10^-1)
P21-14 (10^-2)
P21-17 10^-3
P21-22 (10^-3.)
P21-19 (10^-4.)
P21-20 (10^-5.)
1-1.18 10^-6. (MV)
( ) DENOTES READOUT
10^0 DEC BUFFER
10^-1 DEC BUFFER
10^-2 DEC BUFFER
10^-3 DEC BUFFER
10^-4 DEC BUFFER
VDC BUFFER
4. ALL RESISTORS ARE 1/4 WATT, 10%
3 ALL DIODES ARE TYPE 1G3195 (1G3193)
2. ALL CAPACITORS ARE MYLAR, 100VDC 10%
1. ALL TRANSISTORS ARE TYPE 2N1309.
NOTES: UNLESS OTHERWISE SPECIFIED.
P21-6 .1V
P21-7 1V
P21-8 10V
P21-9 100V
P21-10 1000V
P21-11 1SEC
P21-12 .1SEC
P21-13 .01SEC
P22-11 .01 SEC OUTPUT
P22-13 .1 SEC OUTPUT
P22-17 END OF SCAN
REVISIONS
SYM ZONE EFFECT DESCRIPTION DATE APPROVED
PARTS LIST
QTY REQD PART OR IDENTIFYING NO. NOMENCLATURE OR DESCRIPTION MFR CODE CIRCUIT REF ITEM NO NEXT ASSY FINAL ASSY NEXT ASSY FINAL ASSY
APPLICATION QTY.
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON DECIMALS ± .010 ANGLES ± 0° 30' FRACTIONS ± 1/32
SURFACE ROUGHNESS PER MIL STD-10
DO NOT SCALE THIS DRAWING
RELEASE DATE
MATERIAL
FINISH
DRAWN J.BRADLEY 12-30-63
CHECK
APPR R.N.I 8-11-64
NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA
SCHEMATIC, BUFFER
SERIES 2900
CODE IDENT NO 03626
SIZE D
3408
SCALE
WEIGHT
SHEET 2 of 2
3408 SHEET 2



NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL RESISTORS ARE ¼W, 10%
2. ALL DIODES ARE TYPE IN695(2003-082)
3. ALL CAPACITORS ARE 100V, 20%.
4. ALL TRANSISTORS ARE TYPE 2N1304

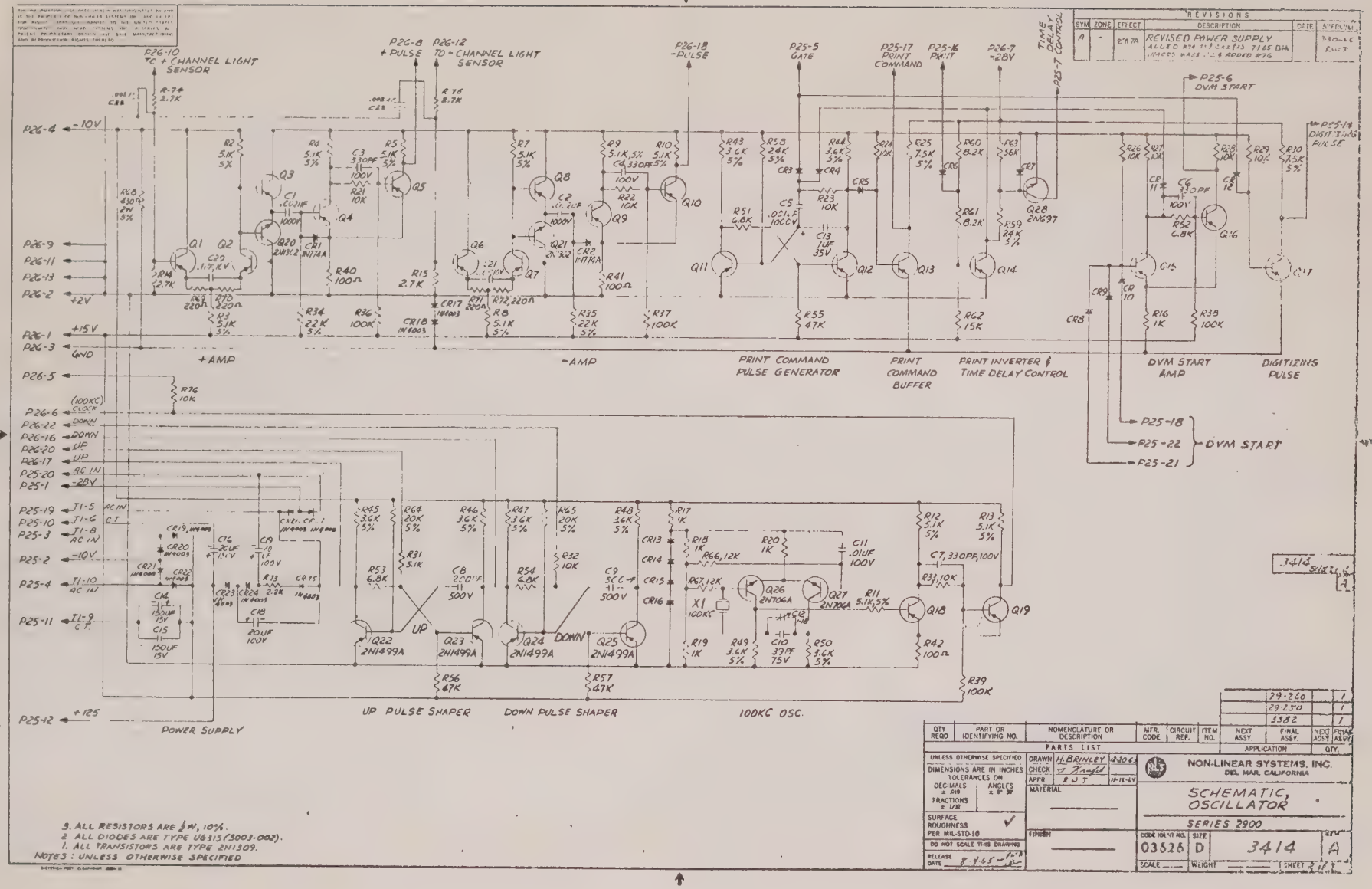
NON-LINEAR SYSTEMS INC.
DEL MAR, CALIFORNIA

SCHEMATIC, CONTROL BOARD

SERIES 2000

DRAWING NO. 03626 SIZE E 3411

SCALE WEIGHT SHEET 1 OF 1



SYM	ZONE	EFFECT	DESCRIPTION	DATE	APPROVAL
A	-	2717A	REVISED POWER SUPPLY ALLIED R74 1% 2.21Ω 7185 DIA MACOR WAFER USED & ADDED R76		7-30-65 RJT

NOTES: UNLESS OTHERWISE SPECIFIED
1. ALL TRANSISTORS ARE TYPE 2N1309.
2. ALL DIODES ARE TYPE UG315(5003-002).
3. ALL RESISTORS ARE ½W, 10%.

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.	NEXT ASSY.	FINAL ASSY.	NEXT ASSY	FINAL ASSY
		PARTS LIST				APPLICATION		QTY.	
						29-260		1	
						29-250		1	
						3382		1	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010
FRACTIONS ± 1/32
ANGLES ± 0° 30'
SURFACE ROUGHNESS PER MIL-STD-10 ✓
DO NOT SCALE THIS DRAWING
RELEASE DATE 8-4-65

DRAWN H. BRINLEY 4-30-65
CHECK
APPR R J T 11-16-64
MATERIAL
FINISH

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

SCHEMATIC, OSCILLATOR
SERIES 2900

CODE IDENT NO. 03526 | SIZE D | 3414 | REV A
SCALE | WEIGHT | SHEET 2 of 2

3414 SHEET 2 REV A

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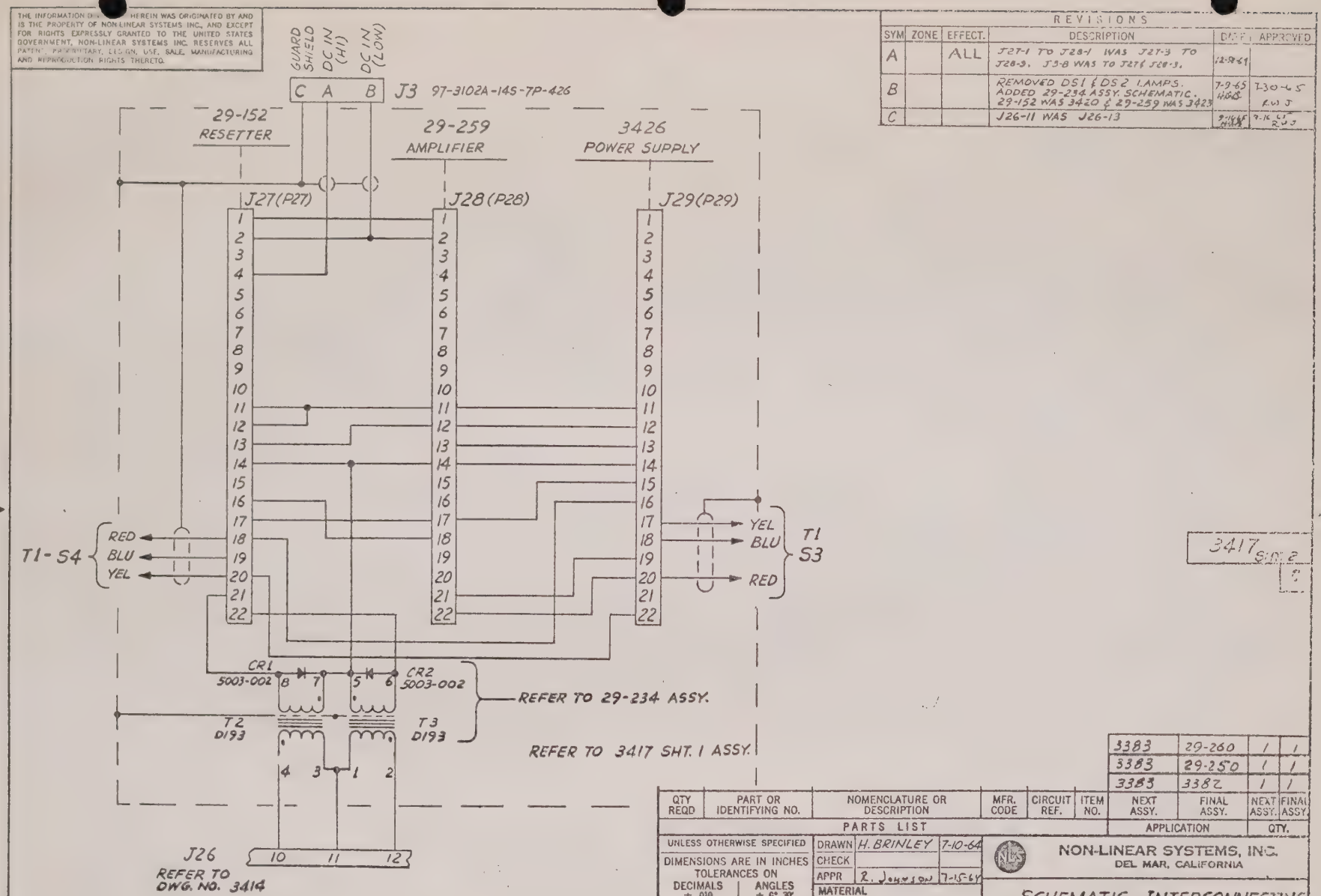
REVISIONS					
SYM	ZONE	EFFECT.	DESCRIPTION	DATE	APPROVED
A		ALL	J27-1 TO J28-1 WAS J27-3 TO J28-3. J3-B WAS TO J27-1 J28-3.	12-9-64	
B			REMOVED DS1 & DS2 LAMPS. ADDED 29-234 ASSY. SCHEMATIC. 29-152 WAS 3420 & 29-259 WAS 3423	7-9-65 HBB	7-30-65 R.W.J
C			J26-11 WAS J26-13	9-16-65 HBB	9-16-65 R.W.J



3417 SHT. 2

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.	NEXT ASSY.	FINAL ASSY.	NEXT ASSY.	FINAL ASSY.
PARTS LIST						APPLICATION		QTY.	
						3383	29-260	1	1
						3383	29-250	1	1
						3383	3382	1	1

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010
ANGLES ± 0° 30'
FRACTIONS ± 1/32
SURFACE ROUGHNESS PER MIL-STD-10 ✓
DO NOT SCALE THIS DRAWING
RELEASE DATE 8-4-65 Rev A & B released

DRAWN H. BRINLEY 7-10-64
CHECK
APPR R. JOHNSON 7-15-64
MATERIAL
FINISH

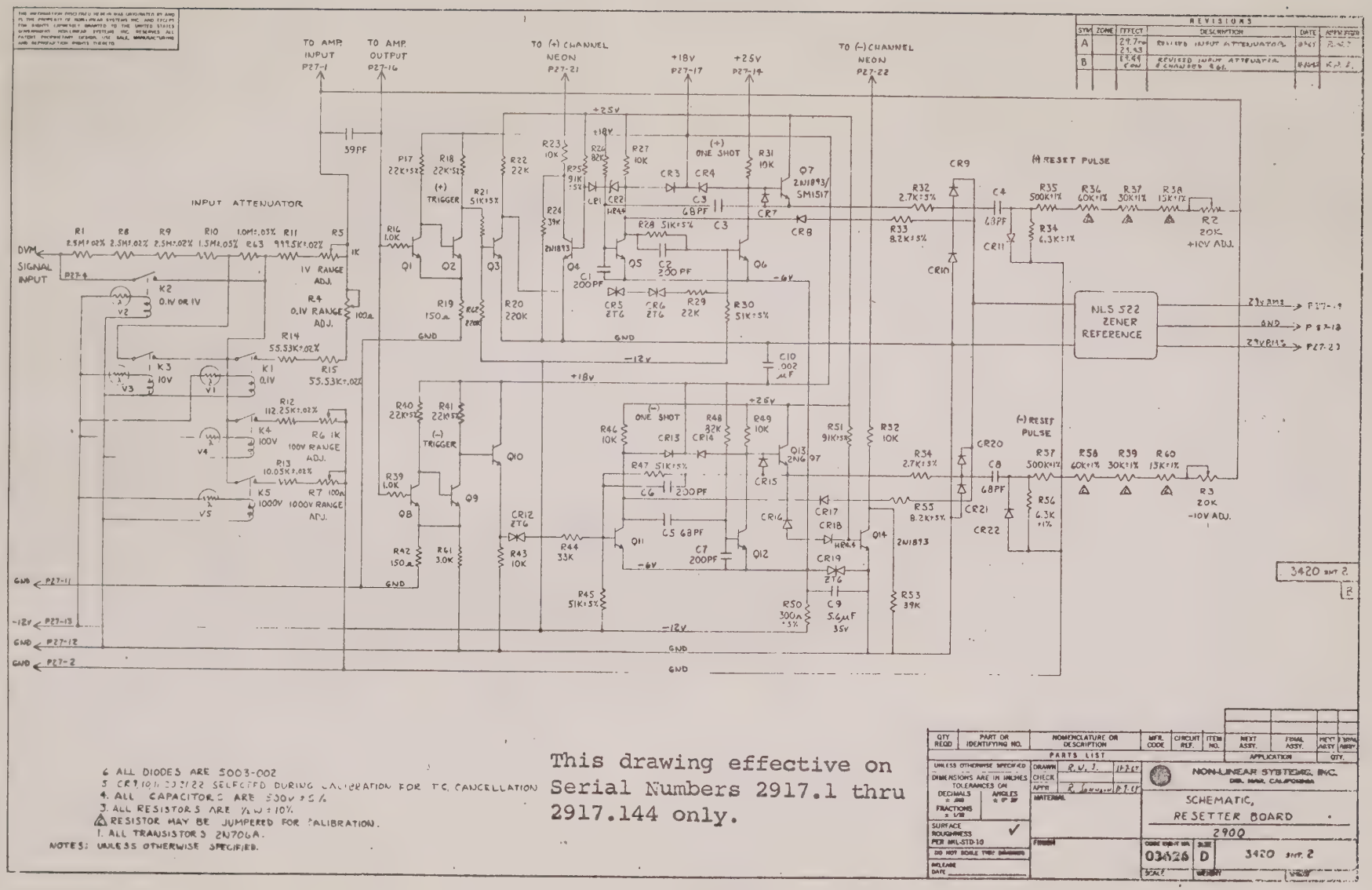
NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

SCHEMATIC, INTERCONNECTING BOARD

2900

CODE IDENT NO. 03626 | SIZE C | 3417

SCALE | WEIGHT | SHEET 2



SYM	ZONE	EFFECT	DESCRIPTION	DATE	APPR'D
A		29.7-144 2917.3	REVISED INPUT ATTENUATOR	8/67	R.V.J.
B		2917.99 & on	REVISED INPUT ATTENUATOR & CHANGED R61	8/68	R.V.J.

6 ALL DIODES ARE 5003-002
5 CR9,10,11,12,17,18 SELECTED DURING CALIBRATION FOR T.C. CANCELLATION
4. ALL CAPACITORS ARE 500V ±5%
3. ALL RESISTORS ARE ¼W ±10%
2 RESISTOR MAY BE JUMPERED FOR CALIBRATION.
1. ALL TRANSISTORS 2N706A.
NOTES: UNLESS OTHERWISE SPECIFIED.

This drawing effective on Serial Numbers 2917.1 thru 2917.144 only.

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.	NEXT ASSY.	FINAL ASSY.	NEXT ASSY	FINAL ASSY
		PARTS LIST				APPLICATION		QTY.	

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES; TOLERANCES ON DECIMALS ± .005, ANGLES ± 0° 30', FRACTIONS ± 1/32; SURFACE ROUGHNESS PER MIL-STD-10; DO NOT SCALE THIS DRAWING; RELEASE DATE

DRAWN R.V.J. 12-3-67; CHECK; APPR R. Jennings 12-5-67; MATERIAL; FINISH

NON-LINEAR SYSTEMS, INC. DEL MAR, CALIFORNIA

SCHEMATIC, RESETTER BOARD 2900

CODE IDENT NO. 03626; SIZE D; 3420 SHT. 2; SCALE; WEIGHT; SHEET

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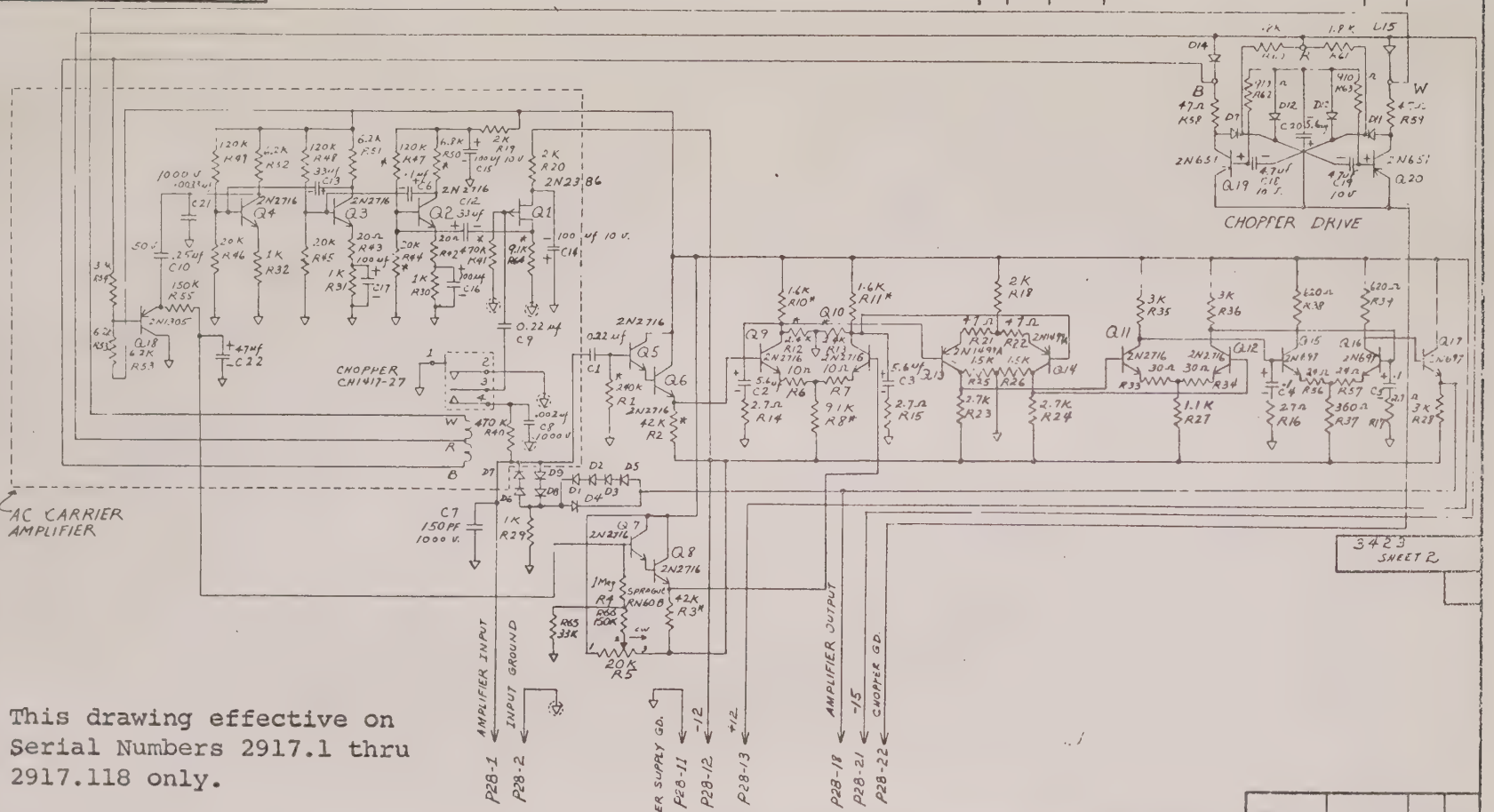
REVISIONS					
SYM	ZONE	EFFECT.	DESCRIPTION	DATE	APPROVED



This drawing effective on Serial Numbers 2917.1 thru 2917.118 only.

1. DIODES D6 THRU D9 ARE IN458, ALL OTHERS ARE 5003-002 (UG-315)
2. ALL RESISTORS ARE ± WATT, 5%, AB EXCEPT THOSE MARKED WITH ASTERISK (*) ARE CORNING C-20.
3. C1, C4, C5 ARE .100 volts. C2, C3, C12, C13, C20 ARE 10 VOLTS. C16, C17 ARE 3 VOLTS.

NOTES: UNLESS OTHERWISE SPECIFIED.

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.	NEXT ASSY.	FINAL ASSY.	NEXT ASSY.	FINAL ASSY
		PARTS LIST				APPLICATION		QTY.	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010
ANGLES ± 0° 30'
FRACTIONS ± 1/32
SURFACE ROUGHNESS PER MIL-STD-10 ✓
DO NOT SCALE THIS DRAWING
RELEASE DATE

DRAWN	BENITO DY	6-26-64
CHECK		
APPR	R W J	7-6-64

MATERIAL
FINISH

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

SCHEMATIC
AMPLIFIER BOARD
2900

CODE IDENT NO. 03626 | SIZE C | 3423
SCALE | WEIGHT | SHEET 2

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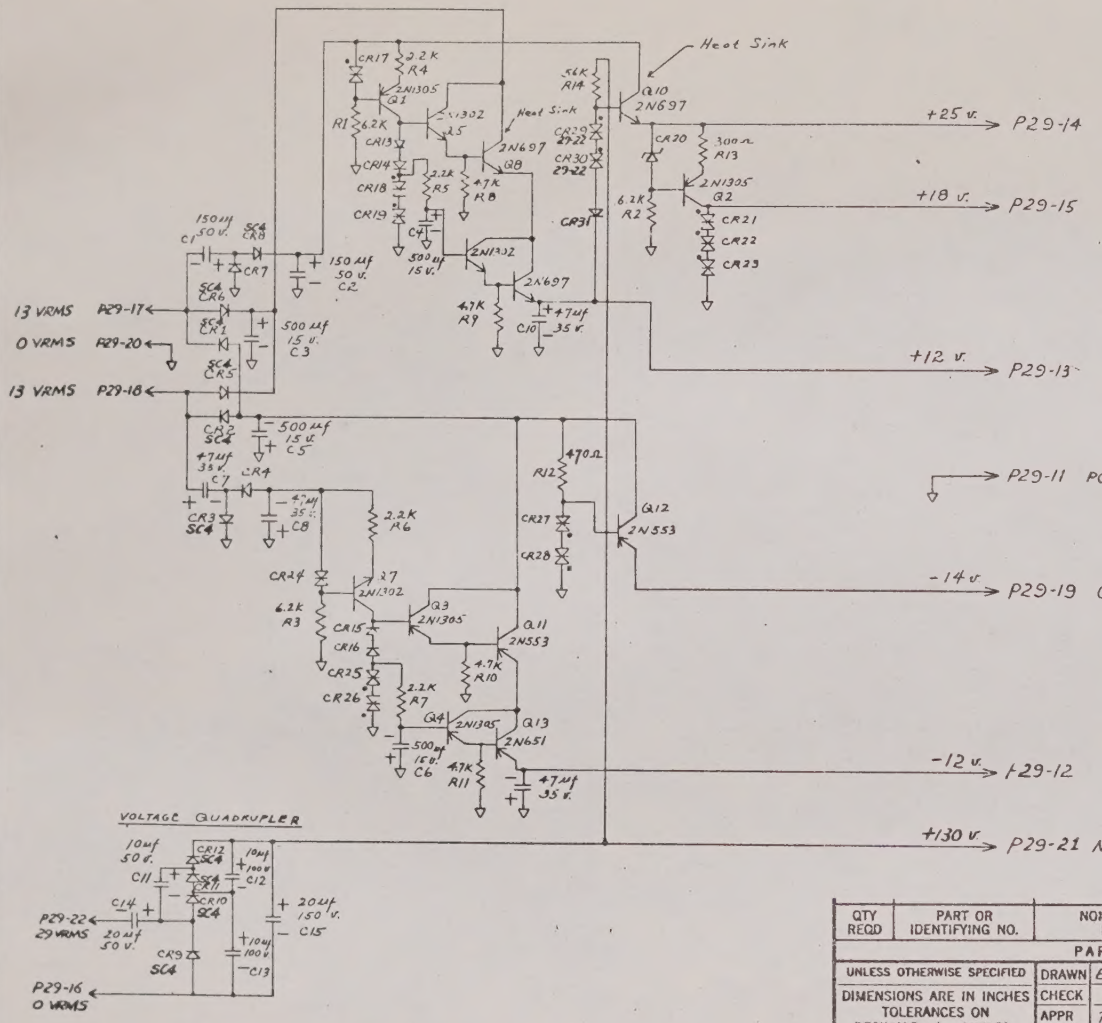
REVISIONS					
SYM	ZONE	EFFECT.	DESCRIPTION	DATE	APPROVED



3426 SHEET 2

1. ALL RESISTORS ARE ± WATT, 10%.
2. ALL ZENER DIODES ARE RT-6.
3. ALL DIODES ARE 5003-002 (U6-315)

NOTES: UNLESS OTHERWISE SPECIFIED

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.	NEXT ASSY.	FINAL ASSY.	NEXT ASSY.	FINAL ASSY.
		PARTS LIST				APPLICATION		QTY.	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010 ANGLES ± 0° 30'
FRACTIONS ± 1/32
SURFACE ROUGHNESS PER MIL-STD-10 ✓
DO NOT SCALE THIS DRAWING
RELEASE DATE

DRAWN	BENITO DY	2-27-64
CHECK		
APPR	R W T	7-6-64

MATERIAL
FINISH

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

SCHEMATIC
POWER SUPPLY BOARD
2900

CODE IDENT NO. 03626 | SIZE C | 3426
SCALE | WEIGHT | SHEET 2

non linear
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